Bt from Daÿ

Lockier.

6 vols

47

661

Lockier.

6 vols
HT
661

THE

GALLERY

OF

NATURE AND ART;

OR,

A TOUR THROUGH CREATION AND SCIENCE.

VOL. I.

Bt from Daj

Lockier.

C

6 Vols
HT
661

THE

GALLERY

OF

NATURE AND ART;

OR,

A TOUR THROUGH CREATION AND SCIENCE.

VOL. I.

THE

GALLERY

OF

NATURE AND ART;

OR,

A TOUR THROUGH CREATION AND SCIENCE.

BY THE REV. EDWARD POLEHAMPTON,

FELLOW OF KING'S COLLEGE, CAMBRIDGE;

Assisted by Distinguished Writers in the various Departments of the Work.

ILLUSTRATED WITH ONE HUNDRED PLATES,

FROM NEW DESIGNS, DESCRIPTIVE OF THE WONDERS OF NATURE AND ART.

BENEATH HIM, WITH NEW WONDER, NOW HE VIEWS,
IN NARROW ROOM, NATURE'S WHOLE WEALTH.

MILTON.

IN SIX VOLUMES.

VOL. I.

LONDON:

PRINTED BY R. WILKS, 89, CHANCERY-LANE;

SOLD BY CRADOCK AND JOY, PATERNOSTER-ROW; RODWELL, NEW BOND-STREET; UNDERWOOD, FLEET-STREET; AND ALL OTHER BOOKSELLERS.

1815.

PREFACE.

AS the boundaries of Science extend, the Discoveries and Curiosities it develops extend also; and as these boundaries have of late years been extended in every direction, it is become impossible for the great body of mankind, or indeed for any one who does not professionally surrender the whole of his life to literary pursuits, to follow up and store in his memory the multiplied facts or discoveries of an amusing, interesting, or extraordinary nature, which have hence been laid open, and are daily growing before us.

A correct and comprehensive Repository, therefore, of whatever is chiefly valuable, and has chiefly a claim upon the public attention, of whatever is intrinsically curious, wonderful, or in any other way impressive, derived from the vast theatres of NATURE and ART, as they are at present unfolded to us; if selected with a judicious and discriminating hand, from the immense mass of matter at this moment before the world, in the various physical and philosophical Transactions, Journals, and Memoirs, the *Ephemerides*, *Amœnitates*, and *Miscellanea Curiosa*, of our own and other countries, cannot fail of becoming an object of public attention and patronage; as peculiarly adapted to the public want, and as combining a rich variety of elegant amusement, with the most valuable specimens of scientific pursuit.

With this feeling the Proprietors of the present work commenced it nearly two years ago, and fully offered their views upon the subject, in a brief Prospectus accompanying

the First Part. And now, that the work is completed, they can conscientiously appeal to the public at large, whether they have not in every respect fulfilled the promise then made, and produced a Miscellany at once elegant and systematic, scientific and entertaining; replete with nearly the whole wealth of NATURE and ART, and therefore fully entitled to be denominated their general Museum or GALLERY. They trust, that they may equally point to the termination, and to the opening of the present work, in proof that its direct scope is to furnish a Literary Conservatory of Rare, Curious, and Interesting Productions, derived from all quarters, and from all ages of the world; from every branch of science so far as it can be rendered popular, and from every department of research and discovery; from the most approved works of Travels and Antiquities; of Topography and general Geography; of Fossils and Mineralogy; of Natural History and Physiology; of Chemistry and Mechanics.

The sanction of mankind, indeed, has already been given to a variety of valuable productions formed upon a basis somewhat similar; several of which, however, have been so long composed, as to become equally antiquated and erroneous in the progressive path of Science; while others, deficient in knowledge or judgment, have been too generally drawn, with little or no discrimination, from wonders and curiosities that have never existed, and exhibit rather a world of fiction than of fact; or have lost all claim to authority, from a vain adoption of the editor's language and opinions instead of the language and opinions of the established sources, from which he should have quoted.

Next, therefore, to the extensive research which the present volumes will be found to offer; a research far exceeding what has ever been attempted before; and the systematic, yet easy and familiar method in which they are arranged; it is their

first and peculiar claim, that they may be depended upon as *primary authorities*; every section, as far as it has been possible, being directly copied, in order to avoid endangering the accuracy or integrity of an approved writer, from his best printed edition, without intermediate transcription or mutilation of any kind. For the sake however of connexion and condensation, it has occasionally been found necessary for the Editor, as he has proceeded, to fill up various chapters with observations of his own,—observations which it is hoped will in many instances be found among the most valuable parts of the work; but such sections or passages have been carefully distinguished from the rest; nor have the words of the original authors been ever deviated from, excepting on a few occasions, where brevity, a style peculiarly uncouth, or some other necessity, has rendered an alteration necessary, of which sufficient notice is given to the reader at the time.

It may be permitted to the Proprietors to observe, that the extent to which this plan has been carried, has led them into an expence and personal labour, far beyond what they had any idea of; but they have readily and cheerfully persevered, as well out of deference to the judgment and zeal of the enlightened Editor, whose recommendations they have in every instance approved and adopted, as from a full persuasion of an ample reward in the approbation and patronage of their countrymen.

The next prominent feature in the present work, to which they are desirous of calling the attention of the Public, is the number and intrinsic excellence of the PLATES, with which it is so richly adorned; and which, they trust, will be found to exalt the GALLERY OF NATURE AND ART above every prior or similar attempt, in no less a degree than the

extent, variety, sound judgment, and authority of its matter. With a few exceptions, for in several instances it has been absolutely necessary to give strict copies, the Plates now offered are from original drawings, expressly designed, and of course expressly engraved for the present work: and it is perhaps only necessary for the reader to examine intrinsically and attentively this highly ornamental and beautiful part of the volumes, to see at once, that the general execution as well in designing as in engraving, is from the hands of some of the most approved Artists of the present day, to whom no less than to the Editor, the Proprietors feel bound in justice to acknowledge their sincere obligations.

It might possibly have added somewhat to the perfection of the present work, to have subjoined a brief sketch of the more interesting and curious particulars in human Physiology and Chorography; embracing the singularities that are occasionally found, and strike us with astonishment, in the general face of particular countries, in the customs and manners of particular tribes, or the extraordinary make or powers of particular individuals: and, in truth, this was originally intended: but it was soon found, that to enter upon such a subject would be to protract the work to an extent of doubtful approbation and expence. It does not form a necessary part of the undertaking, though it might be a useful accompaniment: and, as such, it may yet, perhaps, be attempted in some future period, in two additional volumes, if the sanguine expectations of the Proprietors should be realized, and they should meet with sufficient success in the work as it is now offered to the public.

Nov. 1814.

CONTENTS

OF

VOLUME I.

PART I.

GALLERY OF NATURE.

BOOK I.

Chap. *ASTRONOMY.* Page

BOOK II.

GEOLOGY.

LIST OF PLATES.

With Directions for the Bookbinder.

The LIST of PLATES to be placed after the Preface, and the CONTENTS at the beginning of the different Volumes.

VOLUME I.

VOLUME II.

VOLUME III.

VOLUME IV.

VOLUME V.

VOLUME VI.

THE GALLERY OF NATURE AND ART.

PART I. *NATURE.*

BOOK I. *ASTRONOMY.*

CHAPTER I.

ASTRONOMY OF THE ANCIENTS BEFORE THE FOUNDATION OF THE ALEXANDRIAN SCHOOL.

A CONTEMPLATION * of the Heavens must at all times have fixed the attention of mankind; and especially in those happy climates where the serenity of the atmosphere invited them to observe the Stars. Agriculture required that the seasons should be distinguished and their returns known. It could not be long before it was discovered that the rising and setting of the stars, when they plunge themselves in the Sun's rays, or when they again disengage themselves from his light, might answer this purpose. Hence we find, that among most nations this species of observations may be

* This chapter, extracted from La Place, is given as nearly as may be from the translation of our own Astronomer Royal; but the numerous and unaccountable errors of this translation have compelled us to a perpetual collation with the original, and to alterations in every page.—Editor.

traced back to such early times, till their origin is lost. But some rude remarks on the rising and setting of the stars could not constitute a science. Astronomy did not commence till observations being registered and compared, and the celestial motions examined with greater care, some attempt was made to explain their motions and their laws.

The motion of the sun in an orbit inclined to the equator; the motion of the moon, its phases and eclipses; a knowledge of the planets and their revolutions, and of the sphericity of the earth, were probably the objects of this ancient astronomy, but the few monuments of it that remain are insufficient to ascertain either its epoch or its extent. We can only judge of its great antiquity, by the astronomical periods which it has transmitted to us, by some just notions which the Egyptians and Chaldeans seem to have had of the system of the world, and by the exact relation of the ancient measures to the circumference of the earth. Such has been the vicissitude of human affairs, that that of the arts which could alone transmit the events of past ages in a durable manner, being of modern invention, the remembrance of the first inventors has been entirely effaced. Great nations, whose names are hardly known in history, have disappeared from the soil which they inhabited; their annals, their language, and even their cities have been obliterated, and nothing is left of their science or their industry, but a confused tradition, and some scattered ruins, of doubtful and uncertain origin.

It appears that the practical astronomy of these early ages, was confined to the observations of eclipses, the rising and setting of the principal stars, with their occultations by the moon and planets. The path of the sun was followed by means of the stars which were eclipsed by the twilights, and perhaps by the variations in the meridian shadow of the gnomon. The motion of the planets was determined by the stars which they came nearest to in their course. To distinguish these bodies, and recognize their various motions, the heaven was divided into constellations. And that zone from which the sun, moon, and planets, were never seen to deviate, was called the zodiac. It was divided into the twelve following constellations: Aries, Taurus, Gemini, Cancer, Leo, Virgo, Libra, Scorpio, Sagittarius, Capricornus, and Pisces. These were called *Signs*, because they served to distinguish the seasons. Thus the en-

trance of the sun into Aries, in the time of Hipparchus, marked the commencement of the spring, after which it described the other signs, Taurus, Gemini, &c. but the retrograde motions of the equinoxes, changed the coincidence of the seasons; nevertheless, observers accustomed to mark the commencement of the spring by the entrance of the sun into the sign Aries, have continued to characterise this season in the same manner, and have distinguished the signs of the zodiac from the constellations, the first being ideal, and serving only to designate the course of the sun in the ecliptic. Now, however, that we endeavour to refer our ideas to the most simple expressions, we begin no longer to use the signs of the zodiac, but mark the positions of the heavenly bodies on the ecliptic, according to their distance from the equinoctial point.

Some of the names given to the constellations of the zodiac, appear to relate to the motion of the sun. Cancer, for example, seems to indicate the retrogradation of this body from the solstice, and Libra, or the Balance, denotes the equality of day and night. And other names seem to refer to the climate and agriculture of those nations to whom the zodiac owes its origin. The most ancient observations that have been transmitted to us with sufficient detail, are three eclipses of the moon, observed at Babylon in the years 719 and 720 before the Christian æra. Ptolemy, who cites them in his Almagest, employs them in his determination of the motion of the moon. It is certain, that neither he nor Hipparchus could obtain any that were more ancient, for the exactness of the comparison is in proportion to the interval which separates the extreme observations. This consideration should diminish our regret for the loss of nineteen hundred years of observations by the Chaldeans, and of which they boasted in the time of Alexander, and which Aristotle obtained by means of Calysthenes. But they could only have discovered the period of 6,585 days, by a long series of observations. This period, called the *saros,* has the advantage of bringing back the moon to nearly the same period, with respect to its node, its perigee, and to the sun. Thus, the eclipses observed in one period, afford an easy method of calculating those which are to happen in the succeeding ones. The lunar-solar period of six hundred years, seems to have been known to the Chaldeans. These two periods suppose a knowledge nearly approximating to the true length of the year; it is also highly probable, that they

had remarked the difference between the sidereal and tropical year, and that they were acquainted with the use of the gnomon and sun-dial. And finally, some of them were led from considering the spectacle of nature, to suppose that comets, like planets, are subject to fixed periods, which are regulated by external laws.

Astronomy is not less ancient in Egypt than in Chaldea. The Egyptians were acquainted, long before the christian æra, with the excess of the year, of one quarter of a day beyond 365 days: on this knowledge, they formed the sothic period of 1460 years, which, according to them, brought back the same seasons, months, and festivals of their years, whose length was 365 days. The exact direction of the sides of their pyramids with the four cardinal points, give us a very advantageous idea of their accuracy of observation. It is probable that they had also methods of calculating eclipses. But that which reflects most honour to their astronomy, was the sagacious and important observation of the motion of Mercury and Venus about the sun. The reputation of their priests attracted to them the greatest philosophers of Greece; and, according to all appearance, the school of Pythagoras is indebted to them for the sound notions they professed relative to the system of the universe.

Among these people, astronomy was only cultivated in their temples, and by priests, who made no other use of their knowledge than to consolidate the empire of superstition, of which they were the ministers. They carefully disguised it under emblems, which presented to credulous ignorance, heroes and gods, whose actions were only allegories of celestial phenomena, and of the operations of nature; allegories which the power of imitation, one of the chief springs of the moral world, has perpetuated to our own days, and been mingled with our religious institutions. The better to enslave the people, they profited by their natural desire of penetrating into futurity, and created astrology. Man being induced, by the illusions of his senses, to consider himself as the centre of the universe, it was easy to persuade him, that the stars influenced the events of his life, and could prognosticate to him his future destiny. This error, dear to his self-love, and necessary to his restless curiosity, seems to have been co-eval with astronomy. It has maintained itself through a very long period, and it is only since the end of the last century, that our knowledge of our true relations with nature, has caused them to disappear. In Persia and in India, the commencement of

astronomy is lost in the darkness which envelops the origin of these people. In no country do they go back so far as in China, by an incontestable series of historical monuments.

The prediction of eclipses, and the regulation of the calendar, were always regarded as important objects, for which a mathematical tribunal was established; but the scrupulous attachment of the Chinese to ancient customs, which extended even to their astronomical rules, has contributed among them to keep this science in a perpetual state of infancy.

The Indian tables indicate a much more refined astronomy: but every thing shows that it is not of an extremely remote antiquity. And here, with regret, I differ in opinion from a learned and illustrious astronomer, who, after having honoured his career by labours useful both to science and humanity, fell a victim to the most sanguinary tyranny, opposing the calmness and dignity of virtue to the revilings of an infatuated people, who wantonly prolonged the last agonies of his existence*.

The Indian tables have two principal epochs, which go back, one to the year 3102, the other to the year 1491 before the Christian æra. These epochs are connected with the mean motions of the sun, moon, and planets, in such a manner, that one is evidently fictitious; the celebrated astronomer, above alluded to, endeavours, in his Indian astronomy, to prove, that the first of these epochs is founded on observation. Notwithstanding all the arguments are brought forward with that interest he so well knew how to bestow on subjects the most difficult, I am still of opinion, that this period was invented for the purpose of giving a common origin to all the motions of the heavenly bodies in the zodiac. In fact, computing, according to the Indian tables, from the year 1491, to 3102, we find a general conjunction of the sun and all the planets, as these tables suppose, but their conjunction differs too much from the result of our best tables to have ever taken place, which shows that the epoch to which they refer, was not established on observation. But, it must be owned, that some elements of the Indian astronomy seem to indicate that they have been determined even

---

* Lavoisier, the great founder of the nomenclature of modern chemistry. He was born at Paris, Aug. 26, 1743, and was guillotined May 8, 1794, during the tyranny of Robespierre.—Editor

before this first epoch. Thus the equation of the centre of the sun, which they fix at 2°.4173, could not have been of that magnitude; but at the year 4300 before the Christian æra. But, independently of the errors to which the Indian observations are liable, it may be observed, that they only considered the inequalities of the sun and moon, relative to eclipses, in which the annual equation of the moon is added to the equation of the centre of the sun, and augments it about * 22′, which is very nearly the difference between our determinations and those of the Indians. Many elements, such as the equations of the centre of Jupiter and Mars, are so different in the Indian tables, from what they must have been at their first epoch, that we can conclude nothing in favour of their antiquity from the other elements.

The whole of these tables, particularly the impossibility of the conjunction, at the epoch they suppose, prove on the contrary, that they have been constructed, or at least rectified in modern times. Nevertheless, the ancient reputation of the Indians does not permit us to doubt, that they have always cultivated astronomy, and the remarkable exactness of the mean motions which they have assigned to the sun and moon, necessarily required very ancient observations.

The Greeks did not begin to cultivate astronomy till a long time after the Egyptians, of whom they were the disciples.

It is extremely difficult to ascertain the exact state of their astronomical knowledge, amidst the variety of fable which fills the early part of their history. It appears, however, that they divided the heavens into constellations, about thirteen or fourteen centuries before the Christian æra; for it is to this epoch that the sphere of Eudoxus should be referred. Their numberless schools for philosophy produced not one single observer before the foundation of the Alexandrine school. They treated astronomy as a science purely speculative, often indulging in the most frivolous conjectures.

It is singular, that at the sight of so many contending systems, which taught nothing, the simple reflection, that the only method of comprehending nature is to interrogate her by experiment, never occurred to one of these philosophers, though so many were en-

* 11′ 52″.

dowed with an admirable genius. But we must reflect, that the first observation only presenting insulated facts, little suited to attract the imagination, impatient to ascend to causes, they must have succeeded each with extreme slowness. It required a long succession of ages to accumulate a sufficient number, to discover, among the various phenomena, such relations, which, by extending themselves, should unite with the interest of truth, that of such general speculations as the human understanding delights to indulge in.

Nevertheless, in the philosophic dreams of Greece, we trace some sound ideas, which their astronomers collected in their travels, and afterwards improved. Thales, born at Miletus, 640 years before our æra, went to Egypt for instruction: on his return to Greece, he founded the Ionian school, and there taught the sphericity of the earth, the obliquity of the ecliptic, and the true causes of the eclipses of the sun and moon; he even went so far as to predict them, employing, no doubt, the periods which had been communicated to him by the priests of Egypt.

Thales had for his successors—Anaximander, Anaximenes, and Anaxagoras; to the first is attributed the invention of the gnomon and geographical charts, which the Egyptians appear to have been already acquainted with.

Anaxagoras was persecuted by the Athenians for having taught these truths of the Ionian school. They reproached him with having destroyed the influence of the gods on nature, by endeavouring to reduce phenomena to immutable laws. Proscribed with his children, he only owed his life to the protection of Pericles, his disciple and his friend, who succeeded in procuring a mitigation of his sentence from death to banishment. Thus, *truth*, to establish itself on earth, has almost always had to combat established prejudices, and has more than once been fatal to those who have discovered it. From the Ionian school arose the chief of one more celebrated. Pythagoras, born at Samos, about 590 years before Christ, was at first the disciple of Thales. This philosopher advised him to travel into Egypt, where he consented to be initiated into the mysteries of the priests, that he might obtain a knowledge of all their doctrines. The Brachmans having then attracted his curiosity, he went to visit them, as far as the shores of the Ganges. On his return to his own country, the despotism under which it groaned, obliged him again to quit it, and he retired to Italy, where he

founded his school. All the astronomical truths of the Ionian school, were taught on a more extended scale in that of Pythagoras; but what principally distinguished it, was the knowledge of the two motions of the earth on itself, and about the sun. Pythagoras carefully concealed this from the vulgar, in imitation of the Egyptian priests, from whom, most probably, he derived his knowledge; but his system was more fully explained, and more openly avowed by his disciple Philalaus.

According to the Pythagorists, not only the planets, but the comets themselves, are in motion round the sun. These are not fleeting meteors formed in the atmosphere, but the mighty works of nature. These opinions, so perfectly correct on the system of the universe, have been admitted and inculcated by Seneca, with the enthusiasm which a great idea, on the subject the most vast of human contemplation, naturally excited in the soul of a philosopher.

"Let us not wonder," says he, "that we are still ignorant of the law of the motion of comets, whose appearance is so rare, that we neither can tell the beginning nor the end of the revolution of these bodies, which descend to us from an immense distance. It is not fifteen hundred years since the stars have been numbered in Greece, and names given to the constellations. The day will come, when, by the continued study of successive ages, things which are now hid, will appear with certainty, and posterity will wonder they have escaped our notice.

The same school taught that the planets were inhabited, and that the stars were suns disseminated in space, being themselves centres of planetary systems. These philosophic views should, from their grandeur and justness, have obtained the suffrages of antiquity; but having been taught with systematic speculations, such as the harmony of the heavenly spheres, and wanting, moreover, that proof which has since been obtained, by the agreement with observations, it is not surprising that their truth, when opposed to the illusions of the senses, should not have been admitted.

[*La Place*, Exposition du Système du Monde.]

CHAP. II.

ASTRONOMY OF THE SCHOOL OF ALEXANDRIA.

Hitherto the practical astronomy of different people has only offered us some rude observations relative to the seasons and eclipses; objects of their necessities or their terrors. Their theoretical astronomy consisted in the knowledge of some periods, founded on very long intervals of time, and of various fortunate conjectures, relative to the constitution of the universe, but mixed with considerable error. We see, for the first time, in the school of Alexandria, a connected series of observations; angular distances were made with instruments suitable to the purpose, and they were calculated by trigometrical methods. Astronomy then took a new form, which the following ages have adopted and brought to perfection. The posititions of the fixed stars were determined, the paths of the planets carefully traced, the inequalities of the sun and moon were better known, and, finally, it was the School of Alexandria that gave birth to the first system of Astronomy, that had ever comprehended an entire plan of the celestial motions. This system was, it must be allowed, very inferior to that of the school of Pythagoras, but being founded on a comparison of observations, it afforded, by this very comparison, the means of its own destruction, and the true system of nature has been elevated on its ruins.

After the death of Alexander, his principal generals divided his empire among themselves, and Ptolemy Soter received Egypt for his share. His munificence and love of the sciences, attracted to Alexandria the capital of his kingdom, a great number of the most learned men of Greece. Ptolemy Philadelphus, who inherited with the kingdom his father's love of the sciences, established them there under his own particular protection. A vast edifice, in which they were lodged, contained both an observatory, and that magnificent library which Demetrius Phalereus had collected with immense trouble and expense. Here they were supplied with whatever books and instruments were necessary to their pursuits; and their emulation was excited by the presence of a prince, who often came amongst them to participate in their conversation and their labours.

Arystillus and Timochares were the first observers of the rising

school; they flourished about the year 300 before the Christian æra. Their observations of the principal stars of the zodiac, enabled Hipparchus to discover the precession of the equinoxes, and Ptolemy, from their observations of the planets, founded his theory of those bodies.

The next astronomer which the school of Alexandria produced, was Aristarchus, of Samos. The most delicate elements of astronomy were the subjects of his investigation. He observed the summer solstice, the year 281 before the Christian æra. He determined the magnitude of the apparent diameter of the sun, which he found equal to the 720th part of the whole circumference, a quantity forming a mean between the two limits which Archimedes assigned, a few years afterwards, to this diameter, by an ingenious method, according to which the solar diameter appeared to him greater than the 200th part of a right angle, and less than the 164th part. But what reflects the greatest honour on the genius of Aristarchus, is the method by which he endeavoured to determine the distance of the sun from the earth. He observed the angle contained between the sun and the moon, at the moment he judged half of the lunar disk to be illuminated by the sun, and having found it just $96^{\circ}.7$, he concluded that the sun was eighteen or twenty times farther from us than the moon. Notwithstanding the inaccuracy of this result, it extended the boundaries of the universe much farther than had been done before. Aristarchus revived the opinion of the Pythagorists, relative to the motion of the earth. But as his writings have not been transmitted to us, we are ignorant to what extent he carried this theory in his explanation of the celestial phenomena. We only know that this judicious astronomer, having reflected that the motion of the earth produced no change in the apparent position of the stars, placed them at a distance incomparably greater than the sun. Thus it appears, that of all the ancient astronomers, Aristarchus had formed the most just notions of the magnitude of the universe.

The celebrity of his successor, Eratosthenes, is principally due to his measure of the earth, and his observations on the obliquity of the ecliptic. Having, at the summer solstice, remarked a deep well, whose whole depth was illuminated by the sun, at Syene, in Upper Egypt, he compared this with the altitude of the sun, observed at the same solstice at Alexandria. He found the celestial arc, contained between the zeniths of these two places, equal to

the 50th part of the whole circumference, and as their distance was estimated at 500 stadia, he fixed at 250 thousand stadia the length of the whole terrestrial circumference. The uncertainty that exists, as to the value of this stadium, does not permit us to appreciate the exactness of this measurement.

Aristotle, Cleomedes, Possidonius, and Ptolemy, have given four other evaluations of the circumference of the earth, equivalent to 400, 300, 240, 180 thousand stadia. The simple relations of these measures to each other, leave room to conjecture, that these different quantities are translations of the same measure in different stadia. The Alexandrian stadium was 400 great cubits, of the same length as the nilometer of Cairo, which, according to Freret, has not been altered for a great number of centuries, and may be traced back to the time of Sesostris; its magnitude is equal to 1.7119 feet, according to some measures lately made with great precision, which gives 684.76 feet, for the value of the stadium of Alexandria. As it is probable this stadium was that of Ptolemy, the circumference of the earth, according to that astronomer, would be 123,256,800 feet, which differs but little from our actual measurement, which fixes it at 123,178,320 feet*.

If the measures of Possidonius, Cleomedes, and Aristotle, are identical with that of Ptolemy, the corresponding stadia are 513.570, 410.856, and 308.142 feet. Now, in comparing a great number of ancient itinerary distances with the actual known distances, we find in antiquity these different stadia so precisely, as to render the identity of these four measures of the earth extremely probable, it is therefore very probable that they all depend on some ancient and very exact measure, either executed with great care, or in which the errors were fortunately compensated, as has since happened in the measure of a degree by Fernal, and even in that by Picard. It is true we know, that Possidonius himself measured an arc of the terrestrial meridian; and his operation, as far as we can judge from the details that have been transmitted to us, was very inexact; but there is reason to think he only proposed to verify some ancient measures of the earth, and that he found them to agree nearly with his own.

---

* Ten millions of metres, according to the new measurement of the French National Institute; the metre being equal to 39.37100 English inches.—Editor.

The observation of Eratosthenes, on the obliquity of the ecliptic, is very valuable, inasmuch as it confirms the diminution of it, determined, *à priori*, by the theory of gravitation. He found the distance between the tropics less than 53.06, and greater than 52.96, which gives us a mean *26.50, for the obliquity of the ecliptic. Hipparchus found no reason to alter this result by his observations.

But of all the astronomers of antiquity, the science is most indebted to Hipparchus of Bithynia, for the great number and extent of his observations, by the important results he obtained, by comparing them with those that had been formerly made by others; and for the excellent method which he pursued in his researches. He flourished at Alexandria about 140 years before our æra. Not content with what had already been done, he determined to recommence every thing, and not to admit any results but those founded on a new examination of former observations, or on new observations, more exact than those of his predecessors.

Nothing affords a stronger proof of the uncertainty of the Egyptian and Chaldean observations on the sun and stars, than the necessity which compelled him to recur to the observations of the Alexandrine school, to establish his theories of the sun, and of the precession of the equinoxes. He determined the length of the tropical year, by comparing one of his observations of the summer solstice, with one made by Aristarchus of Samos forty-five years before; he found it 365.24667 days. This is in excess about four minutes and a half. But he remarks himself on the little reliance that can be placed on a determination from solstitial observations, and on the advantage of employing observations of the equinoxes. Hipparchus recognized that there elapsed 187 days from the vernal equinox, to that of the autumn, and 178 days only from this last equinox to that of the spring. He observed, likewise, that these intervals were unequally divided by the solstices, so that 94 days and a half elapse from the vernal equinox to the summer solstice, and 92 days and a half from this solstice to the autumnal equinox.

To explain these differences, Hipparchus supposed the sun to move uniformly in a circular orbit; but, instead of placing the earth in the centre of it, he supposed it removed the 24th part of the radius, and fixed the apogee at the sixth degree of Gemini.

---

* 23.51

From these data he formed the first solar tables to be found in the history of Astronomy. The equation of the centre, which they suppose was too great, it is very probable, that a comparison with eclipses, in which this equation is augmented by the annual equation of the moon, confirmed Hipparchus in his error, and perhaps even led him into it. He was mistaken also in supposing circular the elliptic orbit of the sun, and that the real velocity of this body was constantly uniform. The contrary is now demonstrated by direct measures of the sun's apparent diameter; but such observations were impossible at the time of Hipparchus, whose solar tables, with all their imperfections, are a lasting monument of his genius, which Ptolemy, three centuries after, respected, but did not attempt to improve.

This great astronomer next considered the motions of the moon; he measured the length of its revolution by comparing eclipses, and determined both the eccentricity and inclination of its orbit; he ascertained the motion of its nodes and of its apogee; and from the determination of its parallax endeavoured to conclude that of the sun, by the breadth of the cone of the terrestrial shadow, in an eclipse at the moment it was traversed by the moon, which led him nearly to the same result as had been obtained by Aristarchus. He made a great number of observations on the planets, but too much the friend of truth to explain their motions by uncertain theories, he left the task of this investigation to his successors. A new star which appeared in his time induced him to undertake a catalogue of the fixed stars, to enable posterity to recognize any changes that might take place in the appearances of the heavens. He was sensible also of the importance of such a catalogue for the observations of the moon and the planets. The method he employed was that of Arystillus and Timochares, and which we have already explained in the First Book. The reward of this long and laborious task was the important discovery of the precession of the equinoxes; in comparing his observations with those of these astronomers, he discovered that the stars had changed their situation with respect to the equator, but had preserved the same latitude with respect to the ecliptic, so that to explain these different changes, it is sufficient to give a direct motion to the celestial sphere round the poles of the ecliptic, which produces a retrograde motion of the equinoxes with respect to the stars. But he announced his discovery with some

reserve, being doubtful of the accuracy of the observations of Arystillus and Timochares. Geography is indebted to Hipparchus for the method of determining places on the earth by their latitude and longitude, for which he first employed the eclipses of the moon. Spherical trigonometry, also, owes its origin to Hipparchus, who applied it to the numberless calculations which these investigations required. His principal works have not been transmitted to us; they perished in the conflagration of the Alexandrine library, and we are only acquainted with them through the Almagest of Ptolemy.

The interval of near three centuries which separated these two astronomers, produced some observers, as Agrippa, Menelaus, and Theon. We may also notice in this interval the reformation of the calendar by Julius Cæsar, and the precise knowledge of the ebbing and flowing of the sea. Possidonius observed the law of this phenomenon, which appertains to astronomy by its evident relation to the motion of the sun and moon, and of which Pliny the naturalist has given a description remarkable for its exactness.

Ptolemy, born at Ptolemais in Egypt, flourished at Alexandria about the year 130 of our æra. Hipparchus had conceived the project of reforming astronomy, and establishing the science on new foundations. Ptolemy continued this labour, too vast to be accomplished by a single individual, and has given a complete treatise on this science in his great work entitled the *Almagest*.

His most important discovery is the evection or libration of the moon. Astronomers previously had only considered the motion of this body relative to eclipses; by following it through its whole course, Ptolemy recognized, that the equation of the centre of the lunar orbit, was less in the sysigies than in the quadratures; he determined the law of this difference, and ascertained its value with great precision. To represent it, he made the moon to move upon an epicycle carried by an eccentric, according to a method attributed to Appolonius the geometrician, and which had before been employed by Hipparchus,

It was a general opinion of the ancients, that the uniform circular motion being the most simple and natural, was necessarily that of the heavenly bodies. This error maintained its ground till the time of Kepler, and for a long time impeded him in his researches. Ptolemy adopted it, and, placing the earth on the centre of the

celestial motions, he endeavoured to represent their inequalities in this false hypothesis. Eudoxus had previously imagined for this object, every planet attached to several concentric spheres, endowed with different motions; but this astronomer not having explained in what manner these spheres, by their action on the planets produce the variety of their motions, his hypothesis hardly deserves notice in a treatise on astronomy. A much more ingenious hypothesis consists in moving along one circumference, of which the earth occupies the centre, that of another circumference, on which moves that of a third, and so on, up to the last circumference, on which the body is supposed to move uniformly. If the radius of one of these circles surpasses the sum of the others, the apparent motion of the body round the earth will be composed of a mean uniform motion, and of several inequalities depending on the proportions of these several radii to each other, and the motions of their centres, and of that of the star. By increasing their number, and giving them suitable dimensions, we may represent the inequalities of this apparent motion. Such is the most general manner of considering the hypothesis of cycles and eccentrics, which Ptolemy adopted in his theories of the sun, moon, and planets. He supposed these bodies in motion round the earth in this order of distances—the Moon, Mercury, Venus, the Sun, Mars, Jupiter, Saturn; astronomers were divided in their opinions as to the position of Mercury and Venus; Ptolemy followed the most ancient opinion, and placed them below the sun; others placed them above, and finally, the Egyptians made them move round it. It is singular, that Ptolemy does not mention this hypothesis, which is equivalent to placing the sun in the centre of the epicycles of these two planets, instead of making them revolve round an imaginary centre. But, being persuaded that his system could only be adapted to the three superior planets, he transferred it to the two inferior, and was misled by a false application of the principle of the uniformity of the laws of nature, which, if he had set out from the discovery of the Egyptians, on the motions of Mercury and Venus, would have led him to the true system of the world. But even, if epicycles could be made to represent the inequalities of the motions of the heavenly bodies, still it would be impossible to represent the variations in their distances. In the time of Ptolemy, these variations were almost insensible in the planets, whose apparent diameters could not

then be measured. But his observations on the moon should have taught him that his hypothesis was erroneous, according to which the diameter of the moon perigee, in the quadratures, should be double of the diameter apogee in the sysigies. The motion in latitude of the planets, was another difficulty to be unexplained by this system; and every inequality which the improvements in the art of observing discovered, incumbered this system with a new epicycle, which, instead of being confirmed by the progress of the science, has only grown more and more complicated; and this should convince us, that it is not that of nature. But in considering it as a method of adapting the celestial motions to calculation, this first attempt of the human understanding towards an object so very complicated, does great honour to the sagacity of its author.

Ptolemy confirmed the motion of the equinoxes, discovered by Hipparchus, by comparing his observations with those of this great astronomer. He established the respective immobility of the stars, their invariable latitude to the ecliptic, and their motion in longitude, which he found * 111″ in every year, as Hipparchus had suspected.

We now know that this motion is very nearly † 154″ annually, which, considering the interval between the observations of Ptolemy and Hipparchus, implies an error of more than one degree in their observations. Notwithstanding the difficulty which attended the determination of the longitude of the stars, when observers had no exact measure of time, we are surprised that so great an error should have been committed, particularly when we observe the agreement of the observations with each other, which Ptolemy cites as a proof of the accuracy of his result. He has been reproached with having altered them, but this reproach is not founded; his error, in the determination of the motion of the equinoxes, seems to have been derived from too great confidence in the result of Hipparchus, relative to the length of the tropical year and the motion of the sun. In fact, Ptolemy determined the longitudes of the stars, by comparing them either with the sun, or with the moon, which was equivalent to a comparison with the sun, since the synodical revolution of the Moon was well known by the means of eclipses. Now, Hipparchus having supposed the year too long,

* 35″.9. † 50″.

and consequently the motion of the sun in longitude too slow, it is clear that this error diminished the longitudes of the sun and moon, employed by Ptolemy. The motion in longitude, which he attributed to the stars, is too small by the arc described by the sun in the time, equal to the error of Hipparchus in the length of the year.

In the time of Hipparchus, the tropical year was 365.24234: this great astronomer supposed it 365.24667; the difference is 433″, and during this interval the sun describes an arc of 47″; this, added to the annual precession of 111″, determined by Ptolemy, gives 158 for the precession, which he would have found, if he had computed from the length of the true tropical year, the error would then have been only 4″.

This remark has led to the examination of another question. It had been generally believed, that the catalogue of Ptolemy, was that of Hipparchus, reduced to his time by means of the annual precession of 111″. This opinion is founded on this circumstance, that the constant error in longitude of his stars, disappear when reduced to the time of Hipparchus. But the explanation which we have given of the cause of this error, justifies Ptolemy from the reproach which has been imputed to him, of having taken the merit of Hipparchus to himself; and it seems right to believe him, when he asserts that he has observed all the stars of his own catalogue, even to the stars of the sixth magnitude. He adds, at the same time, that he found very nearly the same positions of the stars, relatively to the ecliptic, as Hipparchus, so that the difference between these two catalogues must have been very small. Thus, the observations of Ptolemy on the stars, and the true value which he has assigned to the evection, are proofs of his exactness as an observer. It is true, that the three equinoxes which he has observed, are inaccurate; but it appears that, too much prepossessed in favour of the exactness of the solar tables of Hipparchus, he made his observations of the equinoxes, at that time very difficult, coincide with them, as the derangement of his armillary might have been sufficient to explain the errors.

The astronomical edifice raised by Ptolemy, subsisted near fourteen centuries, and now that it is entirely destroyed, his Almagest, considered as a depositary of ancient observations, is one of the most precious monuments of antiquity. Ptolemy has not rendered

less service to geography, in collecting all the known longitudes and latitudes of different places, and laying the foundation of the method of projections, for the construction of geographical charts. He composed a great treatise on optics, which has not been preserved, in which he explained the astronomical refractions: he likewise wrote treatises on the several sciences of chronology, music, gnomonics, and mechanics. So many labours, and on such a variety of subjects, manifest a very superior genius, and will ever obtain him a distinguished rank in the history of science. On the revival of astronomy, when his system gave way to that of nature, mankind avenged themselves on him for the despotism it had so long maintained; and they accused Ptolemy of having appropriated to himself the discoveries of his predecessors; but in his time, the works of Hipparchus, and of the astronomers of Alexandria, must have been sufficiently known to have rendered excusable his not distinguishing what belonged to them from his own discoveries. As to the long continuation of his errors, it must be attributed to the same causes which replunged Europe into darkness. The fame of Ptolemy has met with the same fate as that of Aristotle and Descartes. Their errors were no sooner recognized, than a blind admiration gave way to an unjust contempt, for even in science itself, the most useful revolutions are not always exempt from passion and prejudice.

[*La Place*, Exposition du Système du Monde.]

CHAP. III.

OF ASTRONOMY IN MODERN EUROPE.

It is to the Arabians that modern Europe is indebted for the first rays of light that dissipated the darkness in which it was enveloped during twelve centuries. They transmitted to us the treasure of knowledge which they received from the Greeks who were themselves disciples of the Egyptians; but by a deplorable fatality the arts and sciences disappeared among all these nations, as soon as they had communicated them.

Despotism has for a long period extended its barbarism over those beautiful countries where science first received its origin, and those names which formerly rendered them celebrated, are now unknown in them.

Alphonso, king of Castille, was one of the first sovereigns who encouraged the revival of astronomy in Europe. This science can reckon but few such zealous protectors; but he was ill seconded by the astronomers whom he had assembled at a considerable expense, and the tables which they published did not answer to the great cost they had occasioned.

Endowed with a correct judgment, Alphonso was shocked at the confusion of the circles in which the celestial bodies were supposed to move; he felt that the expedients employed by nature ought to be more simple. "If the Deity," said he, "had asked my advice, "these things would have been better arranged." By these words, which are taxed with impiety, he meant to express that mankind were still far from knowing the true mechanism of the universe.

In the time of Alphonso, Europe was indebted to the encouragement of Frederic II. Emperor of Germany, for the first Latin translation of the Almagest of Ptolemy, which was made from the Arabic version.

We are now arrived at that celebrated epoch when astronomy, escaping from the narrow sphere which had hitherto confined it, raised itself by a rapid and continued progress to the height where

we now behold it. Purbech, Regiomontanus, and Walther, prepared the way to these prosperous days of the science, and Copernicus gave them birth by the fortunate explanation of the celestial phænomena, by means of the motion of the earth on its axis, and round the sun.

Shocked, like Alphonso, at the extreme complication of the system of Ptolemy, he tried to find among the ancient philosophers a more simple arrangement of the universe. He found that many of them had supposed Venus and Mercury to move round the sun: that Nicetas, according to Cicero, made the earth revolve on its axis, and by this means freed the celestial sphere from that inconceivable velocity which must be attributed to it to accomplish its diurnal revolution. He learnt from Aristotle and Plutarch, that the Pythagorists had made the earth and planets move round the sun, which they placed in the centre of the universe. These luminous ideas struck him; he applied them to the astronomical observations which time had multiplied, and had the satisfaction to see them yield, without difficulty, to the theory of the motion of the Earth. The diurnal revolution of the heavens was only an illusion due to the rotation of the earth, and the precession of the equinoxes is reduced to a slight motion of the terrestrial axis. The circles, imagined by Ptolemy, to explain the alternate direct and retrograde motions of the planets, disappeared. Copernicus only saw in these singular phænomena, the appearances produced by the motion of the earth round the sun, with that of the planets: and he concluded, from hence, the respective dimensions of their orbits, which till then were unknown. Finally, every thing in this system announced that beautiful simplicity in the expedients of nature, which delights so much when we are fortunate enough to discover it. Copernicus published it in his work, *On the Celestial Revolutions*; not to shock received prejudices, he presented it under the form of an hypothesis. "Astronomers," said he, "in his dedication to Paul III., being permitted to imagine circles, to explain the motion of the stars, I thought myself equally entitled to examine if the supposition of the motion of the earth, would render the theory of these appearances more exact and simple."

This great man did not witness the success of his work. He died suddenly by the rupture of a blood-vessel, at the age of seventy-one years, a few days after receiving the first proof. He was born

at Thorn, in Polish Prussia, the 19th of February, 1473. After learning the Greek and Latin languages, he went to continue his studies as Cracovia. Afterwards, induced by his taste for astronomy, and by the reputation which Regiomontanus had acquired, he undertook a journey to Italy, where this science was taught with success: being greatly desirous to render himself illustrious by the same career, he followed the lessons of Dominic Maria, at Bologna. When arrived at Rome, his talents obtained him the place of professor: he afterwards quitted this city to establish himself at Fravenberg, where his uncle, then Bishop of Warmia, made him a canon. It was in this tranquil abode, that by thirty-six years of observation and meditation, he established his theory of the motion of the earth. At his death, he was buried in the cathedral of Fravenberg, without any pomp or epitaph; but his memory will exist as long as the great truths which he has again introduced with such evidence, as to have at length dissipated the illusions of the senses, and surmounted the difficulties which ignorance of the laws of mechanics had opposed to them.

These truths had yet to vanquish obstacles of another kind, and which, arising from a respected source, would have stifled them if the rapid progress of all the mathematical sciences had not concurred to support them.

Religion was invoked to destroy an astronomical system, and one of its defenders, whose discoveries did honor to his age and country, was tormented by repeated prosecutions. Bethicus, the disciple of Copernicus, was the first who adopted his ideas; but they were not in great estimation till towards the beginning of the seventeenth century, and then they owed it principally to the labours and misfortunes of Galileo.

A fortunate accident had made known the most wonderful instrument ever discovered by human ingenuity, and which, by giving to astronomical observations a precision and extent hitherto unhoped for, displayed in the heavens new inequalities, and new worlds. Galileo hardly knew of the first trials of the telescope, before he bent his mind to bring it to perfection. Directing it towards the stars, he discovered the four satellites of Jupiter, which shewed a new analogy between the earth and planets; he afterwards observed the phases of Venus, and from that moment he no longer doubted of its motion round the sun. The milky way displayed to him an

infinite number of small stars, which the irradiation confounds to the naked eye, in a white and continued light; the luminous points which he perceived beyond the line which separated the light part of the moon from the dark, made him acquainted with the existence and height of its mountains. At length he observed the appearances occasioned by Saturn's ring, the spots and rotation of the sun. In publishing these discoveries, he showed that they proved incontestibly, the motion of the earth; but the idea of this motion was declared heretical by a congregation of cardinals; and Galileo, its most celebrated defender, was cited to the tribunal of the Inquisition, and compelled to retract this theory, to escape a rigorous prison.

One of the strongest passions is the love of truth in a man of genius. Full of the enthusiasm which a great discovery inspires, he burns with ardour to disseminate it, and the obstacles which ignorance and superstition, armed with power, oppose to it, only irritate and increase his energy. Galileo, convinced by his own observations of the motion of the earth, had long meditated a new work, in which he proposed to develope the proofs of it. But to shelter himself from the persecution of which he had barely escaped being the victim, he proposed to present them, under the form of dialogues between three interlocutors, one of whom defended the system of Copernicus, combated by a Peripatetic. It is obvious, that the advantage would rest with the defender of this system; but, as Galileo did not decide between them, and gave as much weight as possible to the objections of the partisans of Ptolemy, he had a right to expect that tranquillity which his age and labours merited.

The success of these dialogues, and the triumphant manner with which all the difficulties against the motion of the earth were resolved, roused the Inquisition. Galileo, at the age of seventy, was again cited before this tribunal. The protection of the grand Duke of Tuscany could not excuse his appearance. He was confined in a prison, where his opponents required of him a second disavowal of his sentiments, and threatening him with the punishment incurred by contumacy, if he continued to teach the system of Copernicus.

He was compelled to sign this formula of abjuration:

" *I Galileo, in the seventieth year of my age, brought personally*
" *to justice, being on my knees, and having before my eyes the holy*
" *Evangelists, which I touch with my own hands, with a sincere heart*

" and faith, abjure, curse, and detest, the absurdity, error, and heresy, " of the motion of the Earth," &c.

What a spectacle! A venerable old man, rendered illustrious by a long life, consecrated to the study of nature, abjuring on his knees, against the testimony of his own conscience, the truth which he had so evidently proved. A decree of the Inquisition condemned him to a perpetual prison. He was released after a year, at the solicitations of the grand duke; but, to prevent his withdrawing himself from the power of the Inquisition, he was forbidden to leave the territory of Florence.

Born at Pisa, in 1564, he gave early indications of those talents which were afterwards developed. Mechanics owe to him many discoveries, of which the most important is the theory of falling bodies.

Galileo was occupied with the libration of the moon when he lost his sight; he died three years afterwards, at Arcetre, in 1642, regretted by all Europe, which he left enlightened by his labours, and indignant at the judgment passed against so great a man by an odious tribunal.

While this passed in Italy, Kepler, in Germany, developed the laws of the planetary motions. But, previous to the account of his discoveries, it is necessary to look back and to describe the progress of astronomy in the north of Europe, after the death of Copernicus.

The history of this science presents at this epoch a great number of excellent observers. One of the most illustrious was William IV. Landgrave of Hesse-Cassel. He had an observatory built at Cassel, which he furnished with instruments, constructed with care, and with which he observed a long time. He procured two celebrated astronomers, Rothman and Juste Byrye; and Tycho owed to his pressing solicitations, the advantages which Frederic, King of Denmark, obtained for him.

Tycho Brahe, who was one of the greatest observers that ever existed, was born at Knucksturp, in Norway. His taste for astronomy was manifested at the age of fourteen years, on the occasion of an eclipse of the sun which happened in 1560. At this age, when reflection is so rare, the justice of the calculation which announced this phænomenon, inspired him with an anxious desire to know its principles; and this desire was still further increased by

the opposition of his preceptor and family. He travelled to Germany, where he formed connections of correspondence and friendship with the most distinguished persons who pursued astronomy either as a profession or amusement, and particularly with the Landgrave of Hesse-Cassel, who received him in the most flattering manner.

On his return to his own country, he was fixed there by his sovereign, Frederic, who gave him the little island of Huena at the entrance of the Baltic. Here Tycho built a celebrated observatory, which was called Uranibourg: and during an abode of twenty-one years, accumulated a prodigious mass of observations and important discoveries. At the death of Frederic, envy, then unrestrained, compelled Tycho to leave his retreat. His return to Copenhagen did not appease the rage of his prosecutors; the minister, Walchendorp (whose name, like that of all men who have abused the power entrusted to them, ought to be handed down to the execration of all ages), forbad him to continue his observations. Fortunately, Tycho found a powerful protector in the Emperor Rodolph II. who settled on him a considerable pension, and lodged him commodiously at Prague. He died suddenly at this city, on the 24th of October, 1601, in the midst of his labours, and at an age when astronomy might have expected great services from him.

The invention of new instruments, and new improvements, added to the old ones a much greater precision in observation; a catalogue of stars very superior to those of Hipparchus, and Ulugh Beigh; the discovery of that inequality of the moon, which is called variation; that of the inequalities of the motion of the nodes, and of the inclination of the lunar orbit; the interesting remark, that comets are beyond this orbit; a more perfect knowledge of astronomical refraction; finally, very numerous observations of the planets, which have served as the basis of the discoveries of Kepler. Such are the principal services which Tycho Brahe has rendered astronomy. Struck with the objections which the adversaries of Copernicus made to the motion of the earth, and perhaps influenced by the vanity of wishing to give his name to an astronomical system, he mistook that of nature. According to him, the earth is immovable in the centre of the universe; all the stars move every day round the axis of the world; and the sun, in its annual revolution, carries with it the planets. In this system, already known, the ap-

pearances are the same as in that of the motion of the earth. We may, in general, consider any point we chuse; for example, the centre of the moon is immovable, provided we assign the motion with which it is animated in a contrary direction to all the stars.

But, is it not physically absurd to suppose the earth immovable in space, while the sun carries with it the planets in which it is included? How could the distance from the earth to the sun, which agrees so well with the duration of its revolution in the hypothesis of the motion of the earth, leave any doubt of the truth of this hypothesis, in a mind constituted to feel the force of analogy. It must be confessed that Tycho, though a great observer, was not fortunate in his research after causes; his unphilosophical mind had even imbibed the prejudices of astrology, which he tried to defend.

It would, be, however, unjust to judge him with the same rigor as one who should refuse at present to believe the motion of the earth, confirmed by the numerous discoveries made in astronomy since that period.

The difficulties which the illusions of the senses oppose to this theory, were not then completely removed. The apparentdiameter of the fixed stars, greater than their annual parallax, give to these stars on this theory, a real diameter, greater than that of the terrestrial orbit. The telescope, by reducing them to luminous points, make this improbable magnitude disappear. It could not be conceived how these bodies, detached from the earth, could follow its motion. The laws of mechanics have explained these appearances; they have proved, what Tycho had again made doubtful, that a body, falling from a considerable height, and abandoned to the action of gravity alone, ought to fall very nearly in a vertical line, only deviating to the east, by a quantity difficult to estimate accurately by observation from its minuteness, so that at present there is as much difficulty in proving the motion of the earth by a direct experiment, as formerly existed to prove that it should be insensible.

In his later years Tycho Brahe had Kepler for a disciple and assistant. He was born in 1571, at Viel, in the duchy of Wirtemberg, and was one of those extraordinary men whom nature grants now and then to the sciences, to bring to light those great theories which have been prepared by the labour of many centuries.

The career of the sciences did not appear to him proper to sa-

with the ambition he felt of rendering himself illustrious; but the ascendancy of his genius, and the exhortations of Maestlinus, led him to astronomy: and he entered into the pursuit with all the activity of a mind passionately desirous of glory.

The philosopher, endowed with a lively imagination, and impatient to know the causes of the phænomena which he sees, often obtains a glimpse of it, before observation can conduct him to it. Doubtless he might, with greater certainty, ascertain the cause from the phænomena; but the history of science proves to us, that this slow progress has not always been that of inventors.

What rocks has he to fear, who takes his imagination for his guide!

Prepossessed with the cause which it presents to him, instead of rejecting it when contradicted by facts, he alters the facts to make them agree with his hypothesis; he mutilates, if I may be allowed the expression, the work of nature, to make it resemble that of his imagination, without reflecting that time destroys with one hand these vain phantoms, and with the other confirms the results of calculation and experience.

The philosopher who is really useful to the cause of science, is he, who, uniting to a fertile imagination, a rigid severity in investigation and observation, is at once tormented by the desire of ascertaining the cause of the phænomena, and by the fear of deceiving himself in that which he assigns.

Kepler owed the first of these advantages to nature, and the second to Tycho Brahe. This great observer, whom he went to see at Prague, and who had discovered the genius of Kepler, in his earliest works, notwithstanding the mysterious analogies of numbers and figures with which it was filled, exhorted him to devote his time to observation, and procured him the title of Imperial mathematician.

The death of Tycho, which happened a few years afterwards, put Kepler in possession of his valuable collection of observations, of which he made a most noble use, founding on them three of the most important discoveries that have been made in natural philosophy.

It was an opposition of Mars which determined Kepler to employ himself on the motions of this planet, rather than on any other. His choice was fortunate in this respect, that the orbit of Mars,

being one of the most eccentric of the planetary system, the inequalities of his motion are more perceptible, and therefore lead to the discovery of their laws with greater facility and precision. Though the theory of the motion of the earth had made the greater part of those circles with which Ptolemy had embarrassed astronomy disappear, yet Copernicus had substituted many others to explain the real inequalities of the celestial bodies.

Kepler, deceived like him, by the opinion that their motions ought to be circular and uniform, tried a long time to represent those of Mars in this hypothesis. Finally, after a great number of trials, which he has related in detail in his famous work called *Stella Martis,* he overcame the obstacle, which an error, supported by the suffrage of every period, had opposed to him; he discovered that the orbit of Mars is an ellipse, of which the sun occupies one of the foci, and that the motion of the planet is such, that the radius vector, drawn from its centre to that of the sun, describes equal areas in equal times. Kepler extended these results to all the planets, and published from this theory, in 1626, the Rudolphine tables, for ever memorable in astronomy, as being the first founded on the true laws of the planetary motions.

Without the speculations of the Greeks, on the curves formed from the section of a cone by a plane, these beautiful laws might have been still unknown. The ellipse being one of these curves, its oblong figure gave rise, in the mind of Kepler, to the idea of supposing the planet Mars, whose orbit he had discovered to be oval, to move on it; and soon, by means of the numerous properties which the ancient geometricians had found in the conic sections, he became convinced of the truth of this hypothesis. The history of the sciences offers us many examples of these applications of pure geometry, and of its advantages; for every thing is connected in the immense chain of truths, and often a single observation has been sufficient to show the connection between a proposition apparently the most sterile, and the phænomena of nature, which are only mathematical results of general laws.

The perception of this truth probably gave birth to the mysterious analogies of the Pythagorists: they had seduced Kepler, and he owed to them one of his most beautiful discoveries. Persuaded that the mean distances of the planets from the sun, ought to be re-

gulated conformably to these analogies, he compared them a long time, both with the regular geometrical solids, and with the intervals of tones. At length, after seventeen years of meditations and calculation, conceiving the idea of comparing the powers of the numbers which expressed them, he found that the squares of the times of the planetary revolutions, are to each other as the cubes of the major axes of their orbits; a most important law, and which he had the advantage of observing in the system of the satellites of Jupiter, and which extends to the systems of all the satellites.

We might be astonished that Kepler should not have applied the general laws of elliptic motion to comets. But, misled by an ardent imagination, he lost the clue of the analogy, which should have conducted him to this great discovery. The comets, according to him, being only meteors engendered in ether, he neglected to study their motions, and thus stopped in the middle of the career which was open to him, abandoning to his successors a part of the glory which he might yet have acquired. In his time, the world had just begun to get a glimpse of the proper method of proceeding in the search of truth, at which genius only arrived by instinct, frequently connecting errors with its discoveries. Instead of passing slowly through a succession of inductions, from insulated phænomena, to others more extended, and from these to the general laws of nature; it was more easy and more agreeable to subject all the phænomena to the relations of convenience and harmony, which the imagination could create and modify at pleasure.

Thus, Kepler explained the disposition of the solar system, by the laws of musical harmony. We behold him even in his latest works, amusing himself with these chimerical speculations, even so far as to regard them as the "*life and soul*" of astronomy. He has deduced from them the eccentricity of the terrestrial orbit, the density of the sun, its parallax, and other results; the inaccuracy of which, now discovered, is a proof of the errors to which we expose ourselves, in deviating from the rout traced by observation.

After having destroyed the epicycles which Copernicus had preserved; after having determined the curve which the planets describe round the sun, and discovered the laws of their motion; Kepler approached too near to the principle from which these laws were derived, not to anticipate it. Attempts to discover this prin-

ciple often exercised his active imagination; but the moment was not yet arrived to make this last step, which demanded a more profound knowledge of mechanics, and a more perfect state of geometry.

However, amidst the fruitless trials of Kepler, and his numerous errors, the connection of facts conducted him to correct opinions on this subject, in the work in which he published his principal discoveries.

"Gravity," he says in his *Commentary on Mars*, "is only a mu-
"tual and corporeal affection between similar bodies. Heavy
"bodies do not tend to the centre of the world, but to that of the
"round body, of which they form a part; and if the earth were
"not spherical, heavy bodies would not fall towards its centre, but
"towards different points."

If the moon and earth were not retained at their respective distances, they would fall upon each other, the moon passing through to $\frac{53}{54}$ of the distance, and the earth passing through the remainder, supposing them equally dense. He believed also, that the attraction of the moon was the cause of the tides, and he suspected, that the irregularities of the lunar motion were produced by the combined actions of the sun and earth on the moon.

Astronomy owes to Kepler many other useful discoveries. His work on optics is full of new and interesting matter; he there explains the mechanism of vision, which was unknown before him. He assigned the true cause of the *lumiere cendrée* of the moon; but he gave the honour of this discovery to his master, Maestlinus, entitled to notice from this discovery, and from having recalled Kepler to astronomy, and converted Galileo to the system of Copernicus.

Finally, Kepler, in his work entitled, *Stereometria Daliorum*, has presented some conceptions on affinity, which influenced the revolution experienced by geometry towards the end of the last century.

With so many claims to admiration, this great man lived in misery, while judicial astrology, every where honoured, was magnificently recompensed. The astronomers of his time, Descartes himself and Galileo, who might have derived the greatest advantage from his discoveries, do not appear to have perceived their importance.

Fortunately the enjoyment which a man of genius receives from

the truths which he discovers, and the prospect of a just and grateful posterity, console him for the ingratitude of his contemporaries.

Kepler had obtained pensions which were always ill paid: going to the diet of Ratisbon to solicit his arrears, he died in that city the 15th of November, 1630. He had in his latter years the advantage of seeing the discovery of logarithms, and making use of them. This was due to Napier, a Scottish baron; it is an admirable contrivance, an improvement on the ingenious algorithm of the Indians, and which, by reducing to a few days the labor of many months, we may almost say doubles the life of astronomers, and spares them the errors and disgusts inseparable from long calculations;—an invention so much the more gratifying to the human mind, as it is entirely due to its own powers: in the arts man makes use of the materials and forces of nature to increase his powers, but here the whole is his own work.

The labours of Huygens followed soon after those of Kepler and Galileo. Very few men have deserved so well of the sciences, by the importance and sublimity of their researches. The application of the pendulum to clocks is one of the most beautiful acquisitions which astronomy and geography have made, and to which fortunate invention, and to that of the telescope, the theory and practice of which Huygens considerably improved, they owe their rapid progress.

He discovered, by means of excellent object-glasses which he succeeded in constructing, that the singular appearances of Saturn were produced by a very thin ring, with which the planet is surrounded: his assiduity in observing made him discover one of the satellites of Saturn.

He made numerous discoveries in geometry and mechanics: and if this extraordinary genius had conceived the idea of combining his theorems on centrifugal forces with his beautiful investigation on involutes, and with the laws of Kepler, he would have preceded Newton in his theory of curvilinear motion, and in that of universal gravitation. But it is not in such approximations that discovery consists.

Towards the same time, Hevelins rendered himself useful to astronomy, by his immense labours. Few such indefatigable ob-

servers have existed; it is to be regretted that he would not adopt the application of telescopes to quadrants, an invention which gave a precision previously unknown to astronomy.

At this epoch astronomy received a new impulse from the establishment of learned societies.

Nature is so various in her productions and phænomena, of which it is so difficult to ascertain the causes, that it is requisite for a great number of men to unite their intellect and exertions to comprehend and develop her laws. This union is particularly requisite when the sciences in extending approximate, and require mutual support from each other.

It is then, that the natural philosopher has recourse to geometry, to arrive at the general causes of the phænomena which he observes, and the geometrician in his turn interrogates the philosopher, in order to render his own investigation useful, by applying them to experience: and to open in these applications a new road in analysis. But the principal advantage of learned societies is the philosophical feeling on every subject which is introduced into them, and from thence diffuses itself over the whole nation. The insulated philosopher may resign himself without fear to the spirit of system; he only hears contradiction at a distance; but in a learned society the shock of systematic opinions at length destroys them, and the desire of mutually convincing each other establishes between the members an agreement only to admit the results of observation and calculation. Thus experience has proved that since the origin of these establishments true philosophy has been generally extended.

By setting the example of submitting every opinion to the test of severe scrutiny, they have destroyed prejudices which had so long reigned among the sciences, and in which the highest intellects of the preceding ages had participated. Their useful influence on opinion accumulated in our own time, with an enthusiasm which at other periods would have perpetuated them. Finally, it is among them, or by the encouragement they offer, that those grand theories have been formed which are placed above the reach of the vulgar by their comprehensiveness; and which, extending themselves by their numerous occasions in which they are applicable, to nature and to the arts, are inexhaustible sources of delight and intelligence.

Of all the learned societies, the two most celebrated for the number and importance of their discoveries in the sciences, and

particularly in astronomy, are the Academy of Sciences in Paris, and the Royal Society in London.

The first was created in 1666, by Louis XIV. who foresaw the lustre which the arts and sciences were to diffuse over his reign. This monarch, worthily seconded by Colbert, invited many learned strangers to fix themselves in his capital. Huygens availed himself of this flattering invitation; he published his admirable work *De Horologio oscillatorio*, in the bosom of the academy, of which he was one of the first members. He would have finished his days in France, had it not been for the disastrous edict which, towards the end of the last century, deprived it of so many valuable citizens. Huygens, departing from a country in which the religion of his ancestors was proscribed, retired to the Hague, where he was born the 14th of April, 1629, and died there the 15th of June, 1695.

Dominic Cassini was likewise induced to go to Paris by the offers of Louis XIV. During forty years of useful labours, he enriched astronomy with a crowd of discoveries: such are the theory of the satellites of Jupiter, the motions of which he determined from observations of their eclipses; the discovery of the four satellites of Saturn; those of the rotation of Jupiter, of the belts parallel to his equator, of the rotation of Mars, of the zodiacal light, a very approximate knowledge of the Sun's parallax, a very exact table of refractions, and, above all, the complete theory of the libration of the Moon.

The great number of astronomical academicians of extraordinary merit, and the limits of this historical abridgment, do not permit me to give an account of their labors; I shall content myself with observing that the application of the telescope to the quadrant, the invention of the micrometer and heliometer, the successive propagation of light, the magnitude of the earth, its ellipticity, and the diminution of gravity at the equator, are all discoveries due to the Academy of Sciences.

Astronomy does not owe less to the Royal Society of London, the origin of which is a few years anterior to that of the Academy of Sciences. Among the astronomers which it has produced, I shall cite Flamstead, one of the greatest observers that have ever appeared. Halley, rendered illustrious by his travels, undertaken for the advantage of science, by his beautiful investigation concerning comets, which enabled him to discover the return of the

comet in 1759; and by the ingenious idea of employing the transit of Venus over the Sun, in the determination of its parallax. I shall mention, lastly, Bradley, the model for observers, and who will be for ever celebrated for two of the most beautiful discoveries ever made in astronomy, the aberration of the fixed stars, and the nutation of the axis of the earth.

When the application of the pendulum to clocks, and of telescopes to quadrants, had rendered the slightest changes in the position of the celestial bodies perceptible to observers, they endeavoured to determine the annual parallax of the fixed stars; for it was natural to suppose, that so great an extent as the diameter of the terrestrial orbit, would be sensible even at the distance of these stars. Observing them carefully, at every season of the year, there appeared slight variations; sometimes favorable, but more frequently contrary to the effects of parallax. To determine the law of these variations, an instrument of great radius, and divided with extreme precision, was requisite. The artist who executed it, deserves to partake of the glory of the astronomer who owed his discovery to him. Graham, a famous English watch-maker, constructed a great sector, with which Bradley discovered the aberration of the fixed stars, in the year 1727. To explain it, this great astronomer conceived the fortunate idea of combining the motion of the earth with that of light, which Roemer had discovered at the end of the last century, by means of the eclipses of Jupiter's satellites. We are surprised that none of the distinguished philosophers who then existed, and who knew the motion of light, should have paid any attention to the very simple effects which result from it, in the apparent position of the fixed stars. But, the human mind, so active in the formation of systems, has almost always waited till observation and experience have acquainted it with important truths, which its powers of reasoning alone might have discovered.

It is thus that the invention of telescopes has followed by more than three centuries that of lenses, and even then was only owing to accident

In 1745, Bradley discovered by observation, the nutation of the terrestrial axis. In all the apparent variations of the fixed stars, observed with extraordinary care, he perceived nothing which indicated a perceptible parallax. The measures of the degrees of the

terrestrial meridian, and of the pendulum, multiplied in different parts of the globe, of which France gave the example, by measuring the whole arc of the meridian, which crosses it, and by sending the academician to the north and to the equator, to observe the magnitude of these degrees, and the intensity of the force of gravity. The arc of the meridian, comprised between Dunkirk and Barcelona, determined by very precise observations, and forming the base of the most natural and simple system of measures; the voyages undertaken to observe the two transits of Venus over the Sun's disk, in 1761 and 1769, and the exact knowledge of the dimensions of the solar system, which has been derived from these voyages; the invention of achromatic telescopes, of chronometers, of the sextant and repeating circle, the discovery of the planet Uranus, by Herschel, in 1781; that of its satellites, and of two new satellites of Saturn, due to the same observer, all the astronomical theories being brought to perfection, and all the celestial phænomena, without exception, being referred to the principle of universal gravitation:—these, with the discoveries of Bradley, are the principal obligations which astronomy owes to England, which, with the preceding, will always be considered as constituting the most glorious epoch of the science.

[*La Place*, Exposition du Systême du Monde.]

CHAPTER IV.

GENERAL NOTICES ON ASTRONOMY

To the preceding observations of *La Place*, the Editor of the present work has thought right to subjoin the following singular or learned opinions of several of the most esteemed writers on the subject.

Professor Playfair, in an article inserted in the Edinburgh Philosophical Transactions, supports the very high pretensions of the Bramins to Astronomy, and conceives that they are in possession of some observations not less than five thousand years old. Mr. Costard, in a paper on the Chinese Chronology and Astronomy, print-

ed in the Transactions of the Royal Society for 1747, and Mr. Bentley, in Vol.VI. of the Asiatic Researches, offer cogent arguments against any such antiquity of Astronomical knowledge in the East: the latter indeed goes so far as to make the principal tables of the Bramins, which they call Surya Siddhanta, not more than about 733 years old.

Newton thinks that the constellations were arranged by Chiron when the solstitial and equinoctial points were in the middle of the respective constellations. *Phil. Trans. for* 1725.

Mr. Wall, in a paper on astronomical symbols, printed in the Manchester Memoir, Vol. I. 243, derives ☿ (Mercury), from the caduceus; ♀ (Venus), from the sistrum; ♂ (Mars), from the shield and spear; ♃ (Jupiter), from Jr, the contraction or first and last letters of the word; ♄ (Saturn), from the sickle. Frisch, however, derives ♃ from lightning with the eagle.

Alexandre and Baliani thought the Earth revolved around the Moon. *Marian.*

In the account of Gail's Memoir on Synesius's Astrolabe, Maps are attributed to Anaximander 600 years before Christ. *M. Inst.* V. 34.

According to Plutarch, Heraclides and Ecphantus attributed to the Earth a diurnal motion only.

Astronomy was introduced into Spain by the Moors in 1201.

The Mexicans when discovered by the Spaniards had years of 365 days, and added 12 days at the end of every period of 52 years. *Robison. Young's Nat. Phil.*—Editor.

CHAPTER V.

THE CELESTIAL WORLD DISCOVERED; OR, CONJECTURES CONCERNING THE INHABITANTS, PLANTS, AND PRODUCTIONS, OF THE WORLD IN THE PLANETS;

Written in Latin by CHRISTIANUS HUYGENS, and inscribed to his brother CONSTANTINE HUYGENS, late Secretary to his Majesty King William. 8vo. with five cuts of Illustration.

THE ingenious author of this discourse, having spent much time, and taken great pains in making celestial observations and discoveries by telescopes of the largest sizes, and other instruments, and having moreover acquainted himself with the latest and best observations and discoveries made by other modern Astronomers; and having well weighed and considered the import and significancy of them, comes in this book to acquaint his brother the heer Constantine Huygens, (who was also a great lover of these inquiries, and who was the person that furnished him with the excellent telescopes he made use of, wrought with his own hand, wherein he had for his diversion acquired an extraordinary art and dexterity, unknown to any besides himself) and by the publication of it, if he thought fit likewise to acquaint the learned world, what upon the result of all, his opinion and belief was concerning the form, structure, and fabrick of the universe, or the whole visible world, and the reasons and arguments that induced him thereunto, which he hopes may seem reasonable enough to men skilled in geometrical, and astromical sciences; such as he wishes his readers may be. But because he was well aware that many of them might be persons of differing qualifications, and such as could not, or would not understand the cogency of them, or from prepossession would endeavour to carp at, and make arguments against the whole doctrine there delivered, therefore he endeavours to enumerate and obviate such as are most likely to be produced for that end. The first of which he conceives, may be of such as are iguorant of mathematical knowledge, who will be apt to represent it as a whimsey only of a disturbed brain, they

thinking it impossible to measure, or any wise to be ascertained of the magnitudes and distances of the celestial bodies; and as to the earth's motions they look on them as fictions, and not capable of being proved: to such he answers, that he does not assert those things as absolutely demonstrated but rather as probable conjectures, and that he leaves every one free to judge of them as they please. And to such as may think them useless, since they are only conjectural, he answers, upon the same account, all other physical knowledge may be rejected, since that also for the most part is but conjectural; and yet we know the studies of those things are very commendable, and afford great pleasure, satisfaction, and benefit, even to such as think them contradictory to holy writ, to suppose other worlds, or animals then those of the earth; because such are not mentioned in the history of the creation. He thinks there has been enough said to shew that the description of the creation in the Bible, was only with relation to the earth, and not at all with respect to the other parts of the world, then what where here visible; nor can it be detrimental to religion, but will be rather, as he conceives, a means to make men have a lesser esteem of these earthly things, since they are but small, with respect to the other world, and to have a greater veneration and adoration of that wonderful wisdom and providence which is universally displayed through the whole fabrick of the universe. As to the form and disposition of the whole, and of the parts of this universe, he agrees with the system of Copernicus; for the better explication of which he hath added two figures, the first of which shows their order and positions, and the second their comparative magnitudes. And because by reason of the smallness of these figures, the true proportions could not be sufficiently exprest, he has added a particular explication, expressing in numbers, the distances of their orbs from the sun in the center, and the times of their periods in them: next of their particular magnitudes and so of their proportions to each other, and to the body of the sun. And since it hereby appears that the earth is moved about the sun, as well as the other planets, (which all the best of the modern astronomers do now believe, and none but such as are of a more dull apprehension, or are otherwise over powered by their superiors, do deny, or make any scruple positively to assert) and that those planets are enlightened by the sun in the same manner as the earth is, and some of them, as ♄ and ♃, have their own

moons, or secondary planets moving about them, sometimes eclipsing them, and eclipsed by them, as the earth also is by its moon, and that some of them are much bigger, as well as some others smaller than the earth; and so that the magnitudes are not proportioned, either according to their order or their distance; since also they are observed to have the same kinds of motion, both annual and diurnal, therefore he thinks it very probable that they do resemble the earth also in other qualifications; for that we have no argument to the contrary why they should not, nor is this way of reasoning from the agreement in some to a like agreement of other precarious, since it is the most usual method of discovering the insensible parts of the world, by their similitude to the more sensible, as in anatomy we judge of the parts of a creature, by the similitude we find they have to the parts of some other before known. From this topic therefore he thinks we may safely conclude that the other planets have solid bodies, and gravity towards their centers, as the earth hath since, we find them to have the same figure, and the same motions, and the same concomitants, and that they have atmospheres and air, and water, &c. And since it would be too great a depretiating of them, and a too much overvaluing of the earth, to suppose them not to be likewise adorned with the more admirable productions and fabricks of plants, and animals, which more evidently manifest the wisdom and design of the divine architect, which we find the earth to be enriched and beautified with. But to suppose them only lifeless lumps of matter, as earth, water, &c.; or vast deserts, barren mountains, rocks, &c. This he says would sink them too much below the earth in beauty and dignity, which this method of reasoning will in no wise permit. He conceives therefore we must suppose and believe them to have animals as well as the earth; and so of necessity plants for their nourishment. And these possibly not much different from those we have, both as to their outward form, and as to their internal structure, and as to their method of production, or propagation, and their increase or growth. And that if there be any difference, most probably it must arise from the differing distances of those globes from the sun, which is more likely to affect the matter than the form. Wherefore though we cannot be ascertained what these differences are, yet we may reasonably conclude, that they are composed of solids and fluids; for that the production and nutrition of these animals must be made

by fluids; and thence also that the parts of them for motion must be somewhat like those of terrestrial animals; whether beasts, fishes, birds, or insects, that is, they must have legs, finns, wings, &c. Though not exactly the same with ours, since the fluids may be more various, as to their number, and as to their density, and as to their rarefaction and conglaciation, some of these globes being much further off, and somewhat nearer to the sun, and its powerful rays. And so the fluids of ♄ and ♃ may not be so apt to be frozen, nor those of ♀ and ☿, to be rarified into vapours, neither of which would destroy the form and use of water for the vegetation of plants.

And because though we should allow these globes, these ornaments and furniture, yet though we suppose them deprived of the principal production and master-piece of all, and for whose use and benefit all the rest seem to be made, we should too much exalt and over-value this globe of the earth, and too much depreciate all the other. Therefore he thinks we must suppose them to have rational animals also, and that those have all those senses, and other necessary organs for reasoning that men have here, aud that they do use them, and have procured thereby the same advantages, and improvement of that faculty, that in the like cases men have done here upon the earth. And since we find that fire in many cases is of great use, he thinks that we must suppose it common to all the other globes also. But to judge of the magnitude, or exact shape of those animated bodies in the other planets, by the magnitude of those globes, he thinks we have no medium to direct us, since we find that nature does not restrain itself to such rules of measure as might seem the best to us. But since the principal use of reason, which he supposes to be the same as here seems to be for the contemplation of the works of the Creator, and the improvement of arts and sciences, he conceives that those inhabitants do not only contemplate and observe the stars, but that they have also made an astronomy, and cultivated such arts as conduce thereunto; as those of geometry, arithmetic, optics, &c. and that of writing, by which they may register their observations to their posterity. And thence he concludes they must have hands and legs, or such like limbs, and an erect face, by which they may be enabled to perform such actions as are necessary for those purposes, and in general he thinks it probable that they may have many arts and sciences, the same with

livening of the parts of the other planets. And as for the fixed stars, he conceives them to be so many suns, and to be dispersed in the vast expansum of heaven, at various distances, and each of them to have a proper system, and planets moved about them. And though it be impossible for us ever to see those planets, by reason of their vast distance, yet from the analogy that is between the sun and stars, we may judge of the planetary systems about them, and of the planets themselves too, which probably are like the planetary bodies about the sun, (that is) that they have plants and animals, nay, and rational ones too, as great admirers and observers of the heavens as any on the earth. This represents to us a wonderful scheme of the prodigious vastness of the heavens; so that the distance between the earth and the sun, though of 17 millions of *German* miles, is almost nothing to the distance of a fixed star. And because of the difficulty in making observations for this purpose, in the common ways, he therefore proposes a new method of his own for this purpose, which he also explains, and by that one may the better conceive the vastness of the distance of one of the nearest, as for instance, from the sun; which by this way he proves to be 27,664 times the distance of the sun from the earth; and to make this distance yet more comprehensible, he makes use of the former explication, by the time that a cannon-bullet moved as swift, as hath been just now explained. Wherefore multiplying 27664 by 25, he finds that a cannon-bullet, moving a hundred fathom in a second, would be 700,000 years in its journey betwixt us and the fixed stars; here by the way he makes some reflections on *Des Cartesa's Vortices*, and explains his own sentiments concerning the present state of the universe, nor will he trouble his mind about their beginning, or how made, as knowing it to be out of the reach of human knowledge or conjecture.

Upon the whole matter you will here find the ingenious author's opinion, concerning the universe, with all the arguments for it, drawn from the most accurate observations that have been hitherto made that are pertinent thereunto. The only failure seems to some to be in his opinion concerning the moon and secondary planets. Upon which subject there may perhaps be shortly published a brief discourse of one who is of a somewhat differing sentiment.

[*From the translation adopted by the Royal Society*, 1699; *and printed in the Phil. Trans. for the same year.*]

CHAPTER VI.

ON THE NATURE AND CONSTRUCTION OF THE SUN AND FIXED STARS.

AMONG the celestial bodies, the sun is certainly the first which should attract our notice. It is a fountain of light that illuminates the world! it is the cause of that heat which maintains the productive power of nature, and makes the earth a fit habitation for man! it is the central body of the planetary system; and what renders a knowledge of its nature still more interesting to us is, that the numberless stars which compose the universe, appear, by the strictest analogy, to be similar bodies. Their innate light is so intense, that it reaches the eye of the observer from the remotest regions of space, and forcibly claims his notice. Now, if we are convinced that an inquiry into the nature and properties of the sun is highly worthy of our notice, we may also with great satisfaction reflect on the considerable progress that has already been made in our knowledge of this eminent body. It would require a long detail to enumerate all the various discoveries which have been made on this subject; I shall therefore content myself with giving only the most remarkable of them.

Sir Isaac Newton has shown that the sun, by its attractive power, retains the planets of our system in their orbits. He has also pointed out the method by which the quantity of matter it contains may be accurately determined. Dr. Bradley has assigned the velocity of the solar light with a degree of precision exceeding our utmost expectation. Galileo, Scheiner, Hevelius, Cassini, and others, have ascertained the rotation of the sun on its axis, and determined the position of its equator. By means of the transit of Venus over the sun's disc, mathematicians have calculated its distance from the earth; its real diameter and magnitude; the density of the matter of which it is composed; and the fall of heavy bodies on its surface. From the particulars here enumerated, it is obvious that we have already a very clear idea of the vast importance, and powerful influence of the sun, on its planetary system.

And if we add to this the beneficent effects we feel on this globe from the diffusion of the solar rays; and consider that, by well traced analogies, the same effects have been proved to take place on other planets in this system; I should not wonder if we were induced to think that nothing remained to be added in order to complete our knowledge: and yet it will not be difficult to show that we are still very ignorant, at least with regard to the internal construction of the sun. The various conjectures, which have been formed on this subject, are evident marks of the uncertainty under which we have hitherto laboured.

The dark spots in the sun, for instance, have been supposed to be solid bodies revolving very near its surface. They have been conjectured to be the smoke of volcanos, or the scum floating on an ocean of fluid matter. They have also been taken for clouds. They were explained to be opaque masses, swimming in the fluid matter of the sun; dipping down occasionally. It has been supposed that a fiery liquid surrounded the sun, and that by its ebbing and flowing, the highest pats of it were occasionally uncovered, and appeared under the shape of dark spots; and that, by the return of this fiery liquid, they were again covered, and in that manner successively assumed different phases. The sun itself has been called a globe of fire, though perhaps metaphorically. The waste it would undergo by a gradual consumption, on the supposition of its being ignited, has been ingeniously calculated. And in the same point of view, its immense power of heating the bodies of such comets as draw very near to it has been assigned.

The bright spots, or faculæ, have been called clouds of light, and luminous vapours. The light of the sun itself has been supposed to be directly invisible, and not to be perceived unless by reflection; though the proofs, which are brought in support of that opinion, seem to amount to no more than what is sufficiently evident, that we cannot see when rays of light do not enter the eye. But it is time to profit by the many valuable observations that we are now in possession of. A list of successive eminent astronomers may be named, from Galileo down to the present time, who have furnished us with materials for examination.

In supporting the ideas proposed in this paper, with regard to the physical construction of the sun, I have availed myself of the labours of all these astronomers, but have been induced to this only by my

own actual observation of the solar phænomena; which, besides verifying those particulars that had been already observed, gave me such views of the solar regions as led to the foundation of a very rational system. For, having the advantage of former obser. vations, my latest reviews of the body of the sun were immediately directed to the most essential points; and the work was by this means facilitated, and contracted into a pretty narrow compass. The following is a short extract of my observations on the sun, to which I have joined the consequences I now believe myself entitled to draw from them. When all the reasonings on the several phænomena are put together, and a few additional arguments, taken from analogy, which I shall also add, are properly considered, it will be found that a general conclusion may be made which seems to throw a considerable light on our present subject.

In the year 1779, there was on the sun a spot large enough to be seen with the naked eye. By a view of it with a seven-feet reflector, charged with a very high power, it appeared to be divided into two parts. The larger of them, on the 19th of April, measured 1′ 8″.06 in diameter; which is equal in length to more than thirty-one thousand miles. Both together must certainly have extended above fifty thousand. The idea of its being occasioned by a volcanic explosion, violently driving away a fiery fluid, which on its return would gradually fill up the vacancy, and thus restore the sun in that place to its former splendour, ought to be rejected on many accounts. To mention only one, the great extent of the spot is very unfavourable to that supposition. Indeed a much less violent and less pernicious cause may be assigned, to account for all the appearances of the spot. When we see a dark belt near the equator of the planet Jupiter, we do not recur to earthquakes and volcanos for its origin. An atmosphere, with its natural changes, will explain such belts. Our spot in the sun may be accounted for on the same principles. The earth is surrounded by an atmosphere, composed of various elastic fluids. The sun also has its atmosphere, and if some of the fluids which enter into its composition should be of a shining brilliancy, in the manner that will be explained hereafter, while others are merely transparent, any temporary cause which may remove the lucid fluid will permit us to see the body of the sun through the transparent ones. If an observer were placed on the moon, he would see the solid body of our earth only in those

places where the transparent fluids of our atmosphere would permit him. In others, the opaque vapours would reflect the light of the sun, without permitting his view to penetrate to the surface of our globe. He would probably also find that our planet had occasionally some shining fluids in its atmosphere; as, not unlikely, some of our northern lights might not escape his notice, if they happened in the unenlightened part of the earth, and were seen by him in his long dark night. Nay, we have pretty good reason to believe, that probably all the planets emit light in some degree; for the illumination which remains on the moon in a total eclipse cannot be entirely ascribed to the light which may reach it by the refraction of the earth's atmosphere. For instance, in the eclipse of the moon, which happened October 22, 1790, the rays of the sun refracted by the atmosphere of the earth towards the moon, admitting the mean horizontal refraction to be 30′ 50″.8, would meet in a focus above 189 thousand miles beyond the moon; so that consequently there could be no illumination from rays refracted by our atmossphere. It is however not improbable, that about the polar regions of the earth there may be refraction enough to bring some of the solar rays to a shorter focus. The distance of the moon at the time of the eclipse would require a refraction of 54′ 6″, equal to its horizontal parallax at that time, to bring them to a focus so as to throw light on the moon.

The unenlightened part of the planet Venus has also been seen by different persons, and, not having a satellite, those regions that are turned from the sun cannot possibly shine by a borrowed light; so that this faint illumination must denote some phosphoric quality of the atmosphere of Venus. In the instance of our large spot on the sun, I concluded from appearances, that I viewed the real solid body of the sun itself, of which we rarely see more than its shining asmosphere. In the year 1783, I observed a fine large spot, and followed it up to the edge of the sun's limb. Here I took notice that the spot was plainly depressed below the surface of the sun; and that it had very broad shelving sides. I also suspected some part at least of the shelving sides to be elevated above the surface of the sun; and observed that, contrary to what usually happens, the margin of that side of the spot, which was farthest from the limb, was the broadest.

The luminous shelving sides of a spot may be explained by a

gentle and gradual removal of the shining fluid, which permits us to see the globe of the sun. As to the uncommon appearance of the broadest margin being on that side of the spot which was farthest from the limb when the spot came near the edge of it, we may surmise that the sun has inequalities on its surface, which may possibly be the cause of it. For when mountainous countries are exposed, if it should chance that the highest parts of the landscape are situated so as to be near that side of the margin, or penumbra of the spot, which is towards the limb, it may partly intercept our view of it, when the spot is seen very obliquely. This would require elevations at least 5 or 6 hundred miles high; but considering the great attraction exerted by the sun on bodies at its surface, and the slow revolution it has on its axis, we may readily admit inequalities to that amount. From the centrifugal force at the sun's equator, and the weight of bodies at its surface, I compute that the power of throwing down a mountain by the exertion of the former, balanced by the superior force of keeping it in its situation of the latter, is near $6\frac{1}{2}$ time less on the sun, than on our equatorial regions: and as an elevation similar to one of three miles on the earth would not be less than 334 miles on the sun, there can be no doubt but that a mountain much higher would stand very firmly. The little density of the solar body seems also to be in favor of the height of its mountains; for, cæteris paribus, dense bodies will sooner come to their level than rare ones. The difference in the vanishing of the shelving side, instead of explaining it by mountains, may also, and perhaps more satifactorily, be accounted from the real difference of the extent, the arrangement, the height, and the intensity of the shining fluid, added to the occasional changes that may happen in these particulars, during the time in which the spot approaches to the edge of the disc. However, by admitting large mountains on the surface of the sun; we shall account for the different opinions of two eminent astronomers; one of whom believed the spots depressed below the sun, while the other supposed them elevated above it. For it is not improbable that some of the solar mountains may be high enough occasionally to project above the shining elastic fluid, when, by some agitation or other cause, it is not of the usual height; and this opinion is much strengthened by the return of some remarkable spots, which served Cassini to ascertain the period of the sun's rotation. A very high country, or

chain of mountains, may oftener become visible, by the removal of the obstructing fluid, than the lower regions, on account of its not being so deeply covered with it.

In the year 1791, I examined a large spot in the sun, and found it evidently depressed below the level of the surface; about the dark part was a broad margin, or plane of considerable extent, less bright than the sun, and also lower than its surface. This plane seemed to rise, with shelving sides, up to the place where it joined the level of the surface. In confirmation of these appearances, I carefully remarked that the disc of the sun was visibly convex; and the reason of my attention to this particular, was my being already long acquainted with a certain optical deception, that takes place now and then when we view the moon; which is, that all the elevated spots on its surface will seem to be cavities, and all cavities will assume the shape of mountains. But then, at the same time the moon, instead of having the convex appearance of a globe, will seem to be a large concave portion of a hollow sphere. As soon as, by the force of imagination, you drive away the fallacious appearance of a concave moon, you restore the mountains to their protuberance, and sink the cavities again below the level of the surface. Now, when I saw the spot lower than the shining matter of the sun, and an extended plane, also depressed, with shelving sides rising up to the level, I also found that the sun was convex, and appeared in its natural globular state. Hence I conclude that there could be no deception in those appearances.

How very ill would this observation agree with the ideas of solid bodies bobbing up and down in a fiery liquid? with the smoke of volcanos, or scum on an ocean? And how easily it is explained on the foregoing theory. The removal of the shining atmosphere, which permits us to see the sun, must naturally be attended with a gradual diminution on its borders; an instance of a similar kind we have daily before us, when through the opening of a cloud we see the sky, which generally is attended by a surrounding haziness of some short extent; and seldom transits, from a perfect clearness, at once to the greatest obscurity.

August 26, 1792, I examined the sun with several powers, from 90 to 500. It appeared evidently that the black spots are the opaque ground, or body of the sun; and that the luminous part is an atmosphere, which, being interrupted or broken, gives us a

transient glimpse of the sun itself. The 7-feet reflector, which was in high perfection, represented the spots, as it always used to do, much depressed below the surface of the luminous part. Sept. 2, 1792, I saw two spots in the sun with the naked eye. In the telescope I found they were clusters of spots, with many scattered ones besides. Every one of them was certainly below the surface of the luminous disc. Sept. 8, 1792, having made a small speculum, merely brought to a perfect figure on bones, without polish, I found, that by stifling a great part of the solar rays, the object speculum would bear a greater aperture; and thus enabled me to see with more comfort, and less danger. The surface of the sun was unequal; many parts of it being elevated, and others depressed. This is here to be understood of the shining surface only, as the real body of the sun can probably be seldom seen, otherwise than in its black spots. It may not be impossible, as light as a transparent fluid, that the sun's real surface also may now and then be perceived; as we see the shape of the wick of a candle through its flame, or the contents of a furnace in the midst of the brightest glare of it; but this I should suppose will only happen where the lucid matter of the sun is not very accumulated.

Sept. 9, 1792, I found one of the dark spots in the sun drawn pretty near the preceding edge. In its neighbourhood I saw a great number of elevated bright places, making various figures: I shall call them faculæ, with Hevelius; but without assigning to this term any other meaning than what it will hereafter appear ought to be given to it. I saw these faculæ extended, on the preceding side, over about $\frac{1}{6}$ part of the sun; but so far from resembling torches, they appeared like the shrivelled elevations on a dried apple, extended in length, and most of them joined together, making waves, or waving lines. By some good views in the afternoon, I found that the rest of the surface of the sun does not contain any faculæ, except a few on the following, and equatorial part of the sun. Towards the north and south I saw no faculæ; there was all over the sun a great unevenness in the surface, which had the appearance of a mixture of small points of an unequal light; but they are evidently an unevenness or roughness of high and low parts.

Sept. 11, 1792, the faculæ in the preceding part of the sun, were much gone out of the disc, and those in the following come on. A dark spot also was come on with them. Sept. 13, 1792, there

were a great number of faculæ on the equatorial part of the sun, towards the preceding and following parts. There were none towards the poles; but a roughness was visible every where. Sept. 16, 1792, the sun contained many large faculæ, on the following side of its equator, and also several on the preceding side. But none about the poles. They seemed generally to accompany the spots, and probably, as the faculæ certainly were elevations, a great number of them may occasion neighbouring depressions, that is, dark spots.

The faculæ being elevations, very satisfactorily explains the reason why they disappear towards the middle of the sun, and re-appear on the other margin; for, about the place where we lose them, they begin to be edge-ways to our view; and if between the faculæ should lie dark spots, they will most frequently break out in the middle of the sun, because they are no longer covered by the side views of these faculæ.

Sept. 22, 1792, there were not many faculæ in the sun, and but few spots; the whole disc however was very much marked with roughness, like an orange. Some of the lowest parts of the inequalities were blackish. Sept. 23, 1792, the following side of the sun contained many faculæ, near the limb. They took up an arch of about 50°. There were likewise some on the preceding side. The north and south rough as usual; but differently disposed. The faculæ were ridges of elevations above the rough surface. Feb. 28, 1794, by an experiment just then tried, I found it confirmed that the sun cannot be so distinctly viewed with a small aperture and faint darkening glasses, as with a large aperture and stronger ones; this latter is the method I always use. One of the black stops on the preceding margin, which was greatly below the surface of the sun, had next to it a protuberant lump of shining matter, a little brighter than the rest of the sun. About all the spots the shining matter seemed to have been disturbed; and was uneven, lumpy, and zig-zagged in an irregular manner. I call the spots black, not that they are entirely so, but meerly to distinguish them; for there was not one of them which was not partly, or entirely, covered over with whitish and unequally bright nebulosity, or cloudiness. This, in many of them, comes near to an extinction of the spot; and in others seems to bring on a subdivision.

Sept. 28, 1794, there was a dark spot in the sun on the following side. It was certainly depressed below the shining atmosphere, and had *shelving* sides of shining matter, which rose up higher than the general surface, and were brightest at the top. The preceding shelving side was rendered almost invisible, by the overhanging of the preceding elevations; while the following was very well exposed: the spot being apparently such in figure as denotes a circular form, viewed in an oblique direction. Near the following margin were many bright elevations, close to visible depressions. The depressed parts less bright than the common surface. The penumbra, as it is called, about this spot, was a considerable plane, of less brightness than the common surface, and seemed to be as much depressed below that surface as the spot was below the plane. Hence, if the brighness of the sun is occasioned by the lucid atmosphere, the intensity of the brightness must be less where it is depressed; for light, being transparent, must be the more intense the more it is deep.

Oct. 12, 1794, the whole surface of the sun was diversified by inequality in the elevation of the shining atmosphere. The lowest parts were every where darkest; and every little pit had the appearance of a more or less dark spot. A dark spot, on the preceding side, was surrounded by very great inequalities in the elevation of the lucid atmosphere; and its depression below the same was bounded by an immediate rising of very bright light. Oct. 13, 1794, the spot in the sun observed yesterday was drawn so near the margin, that the elevated side of the following part of it hid all the black ground, and still left the cavity visible, so that the depression of the black spots, aud the elevation of the faculæ, were equally evident.

It will now be easy to bring the result of these observations into a very narrow compass. That the sun has a very extensive atmosphere cannot be doubted; and that this atmosphere consists of various elastic fluids, that are more or less lucid and transparent, and of which the lucid one is that which furnishes us with light, seems also to be fully established by all the phænomena of its spots, of the faculæ, and of the lucid surface itself. There is no kind of variety in these appearances that may not be accounted for with the greatest facility, from the continual agitation which we may easily conceive must take place in the regions of such extensive elastic fluids. It

will be necessary, however, to be a little more particular, as to the manner in which I suppose the lucid fluid of the sun to be generated in its atmosphere. An analogy that may be drawn from the generation of clouds in our own atmosphere, seems to be a very proper one, and full of instruction. Our clouds are probably decompositions of some of the elastic fluids of the atmosphere itself, when such natural causes, as in this grand chemical laboratory are generally at work, act on them; we may therefore admit that in the very extensive atmosphere of the sun, from causes of the same nature, similar phænomena will take place; but with this difference, that the continual and very extensive decompositions of the elastic fluids of the sun, are of a phosphoric nature, and attended with lucid appearances, by giving out light.

If it should be objected, that such violent and unremitting decompositions would exhaust the sun, we may recur again to our analogy, which will furnish us with the following reflections. The extent of our own atmosphere, we see is still preserved, notwithstanding the copious decompositions of its fluids, in clouds and falling rain; in flashes of lightning, in meteors, and other luminous phænomena; because there are fresh supplies of elastic vapours, continually ascending to make good the waste occasioned by those decompositions. But it may be urged, that the case with the decomposition of the elastic fluids in the solar atmosphere would be very different, since light is emitted, and does not return to the sun, as clouds do to the earth when they descend in showers of rain. To which I answer, that in the decomposition of phosphoric fluids every other ingredient but light may also return to the body of the sun. And that the emission of light must waste the sun, is not a difficulty that can be opposed to our hypothesis. For as it is an evident fact that the sun does emit light, the same objection, if it could be one, would equally militate against every other assignable way to account for the phenomenon.

There are also considerations that may lessen the pressure of this alledged difficulty. We know the exceeding subtilty of light to be such, that in ages of time its emanation from the sun cannot very sensibly lessen the size of this great body. To this may be added, that very possibly there may also be ways of restoration to compensate for what is lost by the emission of light; though the manner in which this can be brought about should not appear to us. Many of

the operations of nature are carried on in her great labaratory, which we cannot comprehend; but now and then we see some of the tools with which she is at work. We need not wonder that their construction should be so singular as to induce us to confess our ignorance of the method of employing them, but we may rest assured that they are not a mere lusus naturæ. I allude to the great number of small telescopic comets that have been observed; and to the far greater number still that are probably much too small for being noticed by our most diligent searchers after them. Those 6, for instance, which my sister has discovered, I can from examination affirm had not the least appearance of any solid nucleus, and seemed to be mere collections of vapours condensed about a centre. Five more, that I have also observed, were nearly of the same nature. This throws a mystery over their destination, which seems to place them in the allegorical view of tools, probably designed for some salutary purposes to be wrought by them; and, whether the restoration of what is lost to the sun by the emission of light, the possibility of which we have been mentioning above, may not be one of these purposes, I shall not presume to determine. The motion of the comet discovered by Mr. Messier in June 1770, plainly indicated how much its orbit was liable to be changed by the perturbations of the planets; from which, and the little agreement that can be found between the elements of the orbits of all the comets that have been observed, it appears clearly that they may be directed to carry their salutary influence to any part of the heavens.

My hypothesis, however, as before observed, does not lay me under any obligation to explain how the sun can sustain the waste of light, nor to show that it will sustain it for ever; and I should also remark that, as in the analogy of generating clouds, I merely allude to their production as owing to a decomposition of some of the elastic fluids of our atmosphere, that analogy, which firmly rests on the fact, will not be less to my purpose to whatever cause these clouds may owe their origin. It is the same with the lucid clouds, if I may so call them, of the sun. They plainly exist, because we see them; the manner of their being generated may remain an hypothesis; and mine, till a better can be proposed, may stand good; but whether it does or not, the consequences I am going to draw from what has been said, will not be affected by it.

Before I proceed, I shall only point out, that according to the

above theory, a dark spot in the sun is a place in its atmosphere which happens to be free from luminous decompositions; and that faculæ are, on the contrary, more copious mixtures of such fluids as decompose each other. The penumbra which attends the spots, being generally depressed more or less to about half way between the solid body of the sun and the upper part of those regions in which luminous decompositions take place, must of course be fainter than other parts. No spot favourable for taking measures having lately been on the sun, I can only judge, from former appearances, that the regions in which the luminous solar clouds are formed, adding also the elevation of the faculæ, cannot be less than 1843, nor much more than 2765 miles in length. It is true that in our atmosphere the extent of the clouds is limited to a very narrow compass; but we ought rather to compare the solar ones to the luminous decompositions which take place in our aurora borealis, or luminous arches, which extend much farther than the cloudy regions. The density of the luminous solar clouds, though very great, may not be exceedingly more so than that of our aurora borealis. For if we consider what would be the brilliancy of a space of two or three thousand miles deep, filled with such coruscations as we see now and then in our atmosphere, their apparent intensity, when viewed at the distance of the sun, might not be much inferior to that of the lucid solar fluid.

From the luminous atmosphere of the sun I proceed to its opaque body, which by calculation from the power it exerts on the planets we know to be of great solidity; and from the phænomena of the dark spots, many of which, probably on account of their high situations, have been repeatedly seen, and otherwise denote inequalities in their level, we surmise that its surface is diversified with mountains and valleys.

What has been said enables us to come to some very important conclusions, by remarking, that this way of considering the sun and its atmosphere, remvoes the great dissimilarity we have hitherto been used to find between its condition and that of the rest of the great bodies of the solar system. The sun, viewed in this light, appears to be nothing else than a very eminent, large, and lucid planet, evidently the first, or in strictness of speaking, the only primary one of our system; all others being truly secondary to it. Its similiarity to the other globes of the solar system with regard to its

solidity, its atmosphere, and its diversified surface; the rotation on its axis, and the fall of heavy bodies, leads us on to suppose that it is most probably also inhabited, like the rest of the planets, by beings whose organs are adapted to the peculiar circumstances of that vast globe. Whatever fanciful poets might say, in making the sun the abode of blessed spirits, or angry moralists devise, in pointing it out as a fit place for the punishment of the wicked, it does not appear that they had any other foundation for their assertions than meer opinion and vague surmise; but now I think myself authorized, on astronomical principles, to propose the sun as an inhabitable world, and am persuaded that the foregoing observations, with the conclusions I have drawn from them, are fully sufficient to answer every objection that may be made against it.

It may, however, not be amiss to remove a certain difficulty, which arises from the effect of the sun's rays on our globe. The heat which is here, at the distance of 95 millions of miles, produced by these rays, is so considerable, that it may be objected, that the surface of the globe of the sun itself must be scorched up beyond all conception. This may be very substantially answered by many proofs drawn from natural philosophy, which show that heat is produced by the sun's rays only when they act on a calorific medium; they are the cause of the production of heat, by uniting with the matter of fire, which is contained in the substances that are heated: as the collison of flint and steel will inflame a magazine of gunpowder, by putting all the latent fire it contains into action. But an instance or two of the manner in which the solar rays produce their effect, will bring this home to our most common experience.

On the tops of mountains of a sufficient height, at an altitude where clouds can very seldom reach, to shelter them from the direct rays of the sun, we always find regions of ice and snow. Now if the solar rays themselves conveyed all the heat we find on this globe, it ought to be hottest where their course is least interrupted. Again, our aëronauts all confirm the coldness of the upper regions of the atmosphere; and since therefore even on our earth, the heat of any situation depends on the aptness of the medium to yield to the impression of the solar rays, we have only to admit, that on the sun itself, the elastic fluids composing its atmosphere, and the matter on its surface, are of such a nature as not to be capable of any excessive affection from its own rays; and indeed this seems to be proved by

the copious emission of them; for if the elastic fluids of the atmosphere, or the matter contained on the surface of the sun, were of such a nature as to admit of an easy chemical combination with its rays, their emission would be much impeded.

Another well-known fact is, that the solar focus of the largest lens, thrown into the air, will occasion no sensible heat in the place where it has been kept for a considerable time, though its power of exciting combustion, when proper bodies are exposed, should be sufficient to fuse the most refractory substances. It will not be necessary to mention other objections, as I can think of none that may be made, but what a proper consideration of the foregoing observations will easily remove; such as may be urged from the dissimilarity between the luminous atmosphere of the sun and that of our globe will be touched on hereafter, when I consider the objections that may be assigned against the moon's being an inhabitable satellite.

I shall now endeavour, by analogical reasonings, to support the ideas I have suggested concerning the construction and purposes of the sun; in order to which it will be necessary to begin with such arguments as the nature of the case will admit, to show that our moon is probably inhabited. This satellite is of all the heavenly bodies the nearest, and therefore most within the reach of our telescopes. Accordingly we find, by repeated inspection, that we can with perfect confidence give the following account of it. It is a secondary planet, of a considerable size; the surface of which is diversified, like that of the earth, by mountains and valleys. Its situation, with respect to the sun, is much like that of the earth; and, by a rotation on its axis, it enjoys an agreeable variety of seasons, and of day and night. To the moon, our globe will appear to be a very capital satellite; undergoing the same regular changes of illuminations as the moon does to the earth. The sun, the planets, and the starry constellations of the heavens, will rise and set there as they do here; and heavy bodies will fall on the moon as they do on the earth. There seems only to be wanting, in order to complete the analogy, that it should be inhabited like the earth.

To this it may be objected, that we perceive no large seas in the moon; that its atmosphere, the existence of which has even been doubted by many, is extremely rare, and unfit for the purposes of

animal life; that its climates, its seasons, and the length of its days, totally differ from ours; that without dense clouds, which the moon has not, there can be no rain; perhaps no rivers, no lakes. In short, that notwithstanding the similarity which has been pointed out, there seems to be a decided difference in the two planets we have compared. My answer to this will be, that that very difference which is now objected, will rather strengthen the force of my argument than lessen its value: we find, even on our globe, that there is the most striking difference in the situation of the creatures that live on it. While man walks on the ground, the birds fly in the air, and fishes swim in water; we can certainly not object to the conveniences afforded by the moon, if those that are to inhabit its regions are fitted to their conditions, as well as we on this globe are to ours. An absolute, or total sameness, seems rather to denote imperfections, such as nature never exposes to our view; and, on this account, I believe the analogies that have been mentioned are fully sufficient to establish the high probability of the moon's being inhabited like the earth.

To proceed, we will now suppose an inhabitant of the moon, who has not properly considered such analogical reasonings as might induce him to surmise that our earth is inhabited, were to give it as his opinion that the use of that great body, which he sees in his neighbourhood, is to carry about his little globe, that it may be properly exposed to the light of the sun, so as to enjoy an agreeable and useful variety of illumination, as well as to give it light by reflection from the sun, when direct day-light cannot be had. Suppose also that the inhabitants of the satellites of Jupiter, Saturn, and the Georgian planet, were to consider the primary ones, to which they belong, as mere attractive centres, to keep together their orbits, to direct their revolution round the sun, and to supply them with reflected light in the absence of direct illumination. Ought we not to condemn their ignorance, as proceeding from want of attention and proper reflection? It is very true that the earth, and those other planets that have satellites about them, perform all the offices that have been named, for the inhabitants of these little globes; but to us, who live on one of these planets, their reasonings cannot but appear very defective; when we see what a magnificent dwelling-place the earth affords to numberless intelligent beings.

These considerations ought to make the inhabitants of the planets wiser than we have supposed those of their satellites to be. We surely ought not, like them, to say "the sun (that immense globe, whose body would much more than fill the whole orbit of the moon) is merely an attractive centre to us." From experience we can affirm, that the performance of the most salutary offices to inferior planets, is not inconsistent with the dignity of superior purposes; and, in consequence of such analogical reasonings, assisted by telescopic views, which plainly favour the same opinion, we need not hesitate to admit that the sun is richly stored with inhabitants.

This way of considering the sun is of the utmost importance in its consequences. That stars are suns can hardly admit of a doubt. Their immense distance would perfectly exclude them from our view, if the light they send us were not of the solar kind. Besides, the analogy may be traced much further. The sun turns on its axis. So does the star Algol. So do the stars called β Lyræ, δ Cephei, η Antinoi, ο Ceti, and many more; most probably all. From what other cause can we so probably account for their periodical changes? Again, our sun has spots on its surface. So has the star Algol; and so have the stars already named; and probably every star in the heavens. On our sun these spots are changeable. So they are on the star ο Ceti; as evidently appears from the irregularity of its changeable lustre, which is often broken in upon by accidental changes, while the general period continues unaltered. The same little deviations have been observed in other periodical stars, and ought to be ascribed to the same cause. But if stars are suns, and suns are inhabitable, we see at once what an extensive field for animation opens itself to our view.

It is true that analogy may induce us to conclude, that since stars appear to be suns, and suns, according to the common opinion, are bodies that serve to enlighten, warm, and sustain a system of planets, we may have an idea of numberless globes that serve for the habitation of living creatures. But if these suns themselves are primary planets, we may see some thousands of them with our own eyes, and millions by the help of telescopes; when at the same time, the same analogical reasoning still remains in full force, with regard to the planets which these suns may support. In this place, I may however take notice that, from other considerations, the idea of suns or stars being merely the supporters of

systems of planets, is not absolutely to be admitted as a general one. Among the great number of very compressed clusters of stars, given in my catalogues, there are some which open a different view of the heavens to us. The stars in them are so very close together, that notwithstanding the great distance at which we may suppose the cluster itself to be, it will hardly be possible to assign any sufficient mutual distance to the stars composing the cluster, to leave room for crowding in those planets, for whose support these stars have been, or might be, supposed to exist. It should seem therefore highly probable that they exist for themselves; and are in fact only very capital, lucid, primary planets, connected together in one great system of mutual support.

As in this argument I do not proceed on conjectures, but have actual observations in view, I shall mention an instance in the clusters, No. 26, 28, and 35, class 6, of my catalogue of nebulæ, and clusters of stars in the Phil. Trans. vol. 79. The stars in them are so crowded, that I cannot conjecture them to be at a greater apparant distance from each other than 5″; even after a proper allowance for such stars, as on a supposition of a globular form of the cluster, will interfere with each other, has been made. Now if we would leave as much room between each of these stars as there is between the sun and Sirius, we must place these clusters 42104 times as far from us as that star is from the sun. But in order to bring down the lustre of Sirius to that of an equal star placed at such a distance, I ought to reduce the aperture of my 20-feet telescope to less than the 2200th part of an inch; when certainly I could no longer expect to see any star at all. The same remark may be made, with regard to the number of very close double stars; whose apparent diameters being alike, and not very small, do not indicate any very great mutual distance. From which, however, must be deducted all those where the different distances may be compensated by the real difference in their respective magnitudes.

To what has been said may be added, that in some parts of the milky way, where yet the stars are not very small, they are so crowded, that in the year 1792, Aug. 22, I found by the gages, that in 41 minutes of time, no less than 258 thousand of them had passed through the field of view of my telescope. It seems therefore, on the whole, not improbable that, in many cases, stars are

united in such close systems as not to leave much room for the orbits of planets, or comets; and that consequently, on this account also, many stars, unless we would make them mere useless brilliant points, may themselves be lucid planets, perhaps unattended by satellites.

Postscript.—The following observations, which were made with an improved apparatus, and under the most favourable circumstances, should be added to those which have been given. They are decisive with regard to one of the conditions of the lucid matter of the sun.

Nov. 26, 1794, 8 spots in the sun, and several sub-divisions of them, were all equally depressed. The sun was every where mottled. The mottled appearance of the sun was owing to an inequality in the level of the surface. The sun was equally mottled at its poles and at its equator; but the mottled appearances may be seen better about the middle of the disc than towards the circumference, on account of the sun's spherical form. The unevenness arising from the elevation and depression of the mottled appearance on the surface of the sun, seemed, in many places, to amount to as much, or to nearly as much, as the depression of the penumbræ of the spots below the upper part of the shining substance; without including faculæ, which were protuberant. The lucid substance of the sun was neither a liquid, nor an elastic fluid; as was evident from its not instantly filling up the cavities of the spots, and of the unevenness of the mottled parts. It exists therefore in the manner of lucid clouds swimming in the transparent atmosphere of the sun; or rather of luminous decompositions taking place within that atmosphere.

[*Herschel*, Phil. Trans. Abridged, 1795.]


Fig. 1
2
3
b
4
5
a
6
b
c
10
11
d
39
F
40
41
b
42

CHAP. VII.

ON THE CONSTRUCTION OF THE HEAVENS, AND THE ORGANIZATION OF THE CELESTIAL BODIES.

A KNOWLEDGE of the construction of the heavens has always been the ultimate object of my observations, and having been many years engaged in applying my forty, twenty, and large ten feet telescopes, on account of their great space-penetrating power to review the most interesting objects discovered in my sweeps, as well as those who had before been communicated to the public in the *Connoissance des Temps*, for 1784, I find that by arranging these objects in a certain successive regular order, they may be viewed in a new light, and, if I am not mistaken, an examination of them will lead to consequences which cannot be indifferent to an inquiring mind.

If it should be remarked that in this new arrangement I am not entirely consistent with what I have already in former papers said on the nature of some objects that have come under my observation, I must freely confess, that by continuing my sweeps of the heavens, my opinion of the arrangement of the stars and their magnitudes, and of some other particulars, has undergone a gradual change; and indeed when the novelty of the subject is considered, we cannot be surprised that many things formerly taken for granted, should, on examination, prove to be different from what they were generally, but incautiously, supposed to be.

For instance, an equal scattering of the stars may be admitted in certain calculations; but when we examine the milky way, or the closely compressed clusters of stars, of which my catalogues have recorded so many instances, this supposed equality of scattering must be given up. We may also have surmised nebulæ to be no other than clusters of stars disguised by their very great distance, but a longer experience and better acquaintance with the nature of nebulæ, will not allow a general admission of such a principle,

although undoubtedly a cluster of stars may assume a nebulous appearance when it is too remote for us to discern the stars of which it is composed.

Impressed with an idea that nebulæ properly speaking were clusters of stars, I used to call the nebulosity of which some were composed, when it was of a certain appearance, *resolvable*; but when I perceived that additional light, so far from resolving these nebulæ into stars, seemed to prove that their nebulosity was not different from what I had called milky, this conception was set aside as erroneous. In consequence of this, such nebulæ as afterwards were suspected to consist of stars, or in which a few might be seen, were called *easily resolvable*; but even this expression must be received with caution, because an object may not only contain stars, but also nebulosity not composed of them.

It will be necessary to explain the spirit of the method of arranging the observed astronomical objects under consideration in such a manner, that one shall assist us to undertstand the nature and construction of the other. This end I propose to obtain by assorting them into as many classes as will be required to produce the most gradual affinity between the individuals contained in any one class, with those contained in that which precedes and that which follows it: and it will certainly contribute to the perfection of this method, if this connection between the various classes can be made to appear so clearly as not to admit of a doubt. This consideration will be a sufficient apology for the great number of assortments into which I have thrown the objects under consideration; and it will be found that those contained in one article, are so closely allied to those in the next, that there is perhaps not so much difference between them, if I may use the comparison, as there would be in an annual description of the human figure, were it given from the birth of a child till he comes to be a man in his prime.

The similarity of the objects contained in each class will seldom require the description of more than one of them, and for this purpose, out of the number referred to, the selected one will be that which has been most circumstantially observed; however, those who wish either to review any other of the objects, or to read a short description of them, will find their place in the heavens, or the account of their appearance either in the catalogues I have

given of them in the Philos. Trans., or in the *Connoissance des Temps* for 1784, to which in every article proper references will be given for the objects under consideration.

If the description I give should sometimes differ a little from that which belongs to some number referred to, it must be remembered that objects which had been observed many times, could not be so particularly and comprehensibly detailed in the confined space of the catalogues as I now may describe them; additional observations have also now and then given me a better view of the objects than I had before. This remark will always apply to the numbers which refer to the *Connoissance des Temps*; for the nebulæ and clusters of stars are there so imperfectly described, that my own observation of them with large instruments may well be supposed to differ entirely from what is said of them. But if any astronomer should review them, with such high space-penetrating-powers, as are absolutely required, it will be found that I have classed them very properly.

It will be necessary to mention that the nebulous delineations in the figures are not intended to represent any of the individuals of the objects which are described otherwise than in the circumstances which are common to the nebulæ of each assortment: the irregularity of a figure, for instance, must stand for every other irregularity; and the delineated size for every other size. It will however be seen, that in the figure referred to there is a sufficient resemblance to the described nebula to show the essential features of shape and brightness then under consideration.

1. *Of extensive diffused Nebulosity.*

The first article of my series will begin with extensive diffused nebulosity, which is a phenomenon that hitherto has not been much noticed, and can indeed only be perceived by instruments that collect a great quantity of light. Its existence, when some part of it is pointed out by objects that are within the reach of common telescopes, has nevertheless obtruded itself already on the knowledge of astronomers, as will be seen in my third article.

The widely diffused nebulosity under consideration has already been partially mentioned in my catalogues*.

* See Phil. Trans. for 1786, page 471; for 1789, page 226; and for 1802, page 503. The following ten nebulosities are in the Vth class, No. 13, 14, 15, 17, 28, 30, 31, 33, 34, 38.

The description of the object I shall select is of No. 14, in the 5th class, and is as follows: "Extremely faint branching nebulo-"sity; its whitishness is entirely of the milky kind, and it is "brighter in three or four places than in the rest; the stars of the "milky way are scattered over it in the same manner as over the "rest of the heavens. Its extent in the parallel is nearly 1½ de-"gree, and in the meridional direction about 52 minutes. The "following part of it is divided into several streams and windings, "which after separating, meet each other again towards the south." See figure 1.

This account, which agrees with what will be found in all the other numbers referred to, with regard to the subject under consideration, namely, a diffused milky nebulosity, will give us already some idea of its great abundance in the heavens; my next article, however, will far extend our conception of its quantity.

2. *Observations of Nebulosities that have not been published before.*

It may be easily supposed that in my sweeps of the heavens I was not inattentive to extensive diffusions of nebulosity, which occasionally fell under my observation. They can only be seen when the air is perfectly clear, and when the observer has been in the dark long enough for the eye to recover from the impression of having been in the light.

I have collected fifty-two such observations into a table, and have arranged them in the order of right ascension. In the first column they are numbered; in the second and third columns are the right ascension and north polar distance of a place which is the central point of a parallelogram comprehending the space which the nebulosity was observed to fill. They are calculated for the year 1800.

The length and breadth of the parallelograms are set down in the 4th and 5th columns in degrees and minutes of a great circle. The time taken up in the transit of each parallelogram having been properly reduced to space by the polar distance given in the 3d column, in order to make it agree with the space contained in the breadth of the zone described by the telescope; the dimensions of the former space therefore is in the parallel, and that of the latter in the meridian. My field of view, being fifteen minutes in diameter, its extent has been properly considered in the assigned

dimensions of the parallelograms. It is however evident that the limits of the sweeping zone leave the extent of the nebulosity in the meridian unascertained. The beginning of it is equally uncertain, since the nebulous state of the heavens could only be noticed when its appearance became remarkable enough to attract attention. The ending is always left undetermined; for, as the right ascension was only taken once, I have allowed but a single minute of time for the extent of the nebulosity in that direction, except where the time was repeatedly taken with a view to ascertain how far it went in the parallel; or when the circumstances of its brightness pointed out a longer duration.

The sixth column of the table contains the size of the observed nebulosity reduced to square degrees and decimals, computed from the two preceding columns; and in the last I have given the account of these nebulosities as recorded in my sweeps at the time they were made; namely, within a period of nineteen years, beginning in 1783, and ending in 1802.

When this account says *affected*, it is intended to mean that the ground upon which, or through which we see, or may see stars, is *affected with* nebulosity.

Table of extensive diffused Nebulosity.

No.	R. A.	P. D.	Paral.	Merid.	Size.	Account of the Nebulosity.
	h ′ ″	° ′	° ′	° ′	Deg.	
1	0 5 2	81 7	1 44	1 55	3,3	Much affected with nebul.
2	0 12 31	86 34	3 0	2 34	7,7	Much affected.
3	0 17 17	61 24	0 41	2 40	1,8	Affected.
4	0 20 31	86 34	1 30	2 34	3,6	Much affected.
5	0 25 5	67 8	0 29	2 34	1,2	Much affected.
6	0 31 22	90 4	2 30	2 19	5,7	Appeared to be affected with very faint nebulos.
7	0 32 54	49 23	1 33	3 1	4,7	Affected with nebulosity.
8	0 34 21	51 17	1 17	2 49	3,6	Unequally affected.
9	0 36 13	47 3	2 37	3 18	8,6	Suspected faint nebulosity.
10	0 43 32	46 58	0 26	3 18	1,4	Suspected faint nebulosity
11	1 35 32	60 42	0 28	2 40	1,3	Suspected to be tinged with milky nebulosity.
12	2 22 19	71 27	0 29	2 29	1,2	Much affected with nebul.
13	3 56 14	65 6	0 29	2 27	1,7	Much affected.
14	4 17 21	55 7	1 4	2 38	2,8	Suspected pretty strong nebulosity.
15	4 18 21	55 6	1 53	2 38	5,0	Suspected nebulosity.
16	4 21 35	97 44	0 30	2 15	1,1	Strong milky nebulosity.
17	4 23 14	69 23	0 29	2 36	1,3	Much affected.
18	4 38 17	69 23	0 29	2 36	1,3	Much affected.
19	4 46 17	63 25	1 46	2 31	4,4	Strong suspicion of very faint milky nebulosity.
20	5 9 44	65 6	1 23	2 27	3,4	Very much affected.
21	5 13 14	65 6	0 29	2 27	1,7	Affected.
22	5 23 59	97 1	2 31	2 31	6,3	Affected with milky nebul.
23	5 25 16	92 48	0 30	2 40	1,3	Affected.
24	5 27 2	94 23	1 48	2 32	4,6	Visible and unequally bright nebulosity. I am pretty sure this joins to the great nebula in Orion.
25	5 30 40	92 35	2 45	2 33	7,0	Diffused milky nebulosity.
26	5 31 58	97 1	1 56	2 31	4,9	A pretty strong suspicion of nebulosity.
27	5 38 5	88 55	1 6	2 37	2,9	Affected with milky nebu.
28	5 55 55	86 17	0 30	2 34	1,3	Much affected.
29	5 56 36	110 28	1 48	2 48	5,0	Affected.
30	6 33 7	48 39	0 26	3 4	1,3	Affected.
31	9 22 56	108 3	0 29	2 30	1,2	Affected.
32	9 27 19	18 21	0 24	4 4	1,6	Much affected with very faint whitish nebulosity.
33	10 6 56	98 33	3 58	2 17	9,1	Very faint whitish nebulo.
34	10 16 1	37 58	0 24	4 9	1,7	Much affected.

No.	R. A.	P. D.	Paral.	Merid.	Size.	Account of the Nebulosity.
	h ′ ″	° ′	° ′	° ′	Deg.	
35	10 34 29	26 44	0 29	3 15	1,6	Affected with very faint nebulosity.
36	10 58 24	26 44	0 42	3 15	2,3	Affected.
37	11 56 59	58 50	0 41	2 54	2,0	Affected with whitish neb.
38	12 7 34	58 50	0 41	2 54	2,0	Affected with whitish neb.
39	13 7 33	55 20	0 27	2 17	1,0	Much affected.
40	13 58 0	55 20	0 42	2 17	1,6	Very much affected; and many faint nebulæ suspected.
41	15 5 7	70 40	1 52	2 31	4,7	Affected with very faint nebulosity.
42	20 58 20	92 17	1 45	2 21	4,1	Much affected with whitish nebulosity.
43	20 48 50	73 38	0 29	2 52	1,4	A good deal affected.
44	20 51 4	46 51	0 59	2 53	2,8	Faint milky nebulosity scattered over this space, in some places pretty bright.
45	20 52 28	91 57	0 49	0 56	0,8	Much affected with whitish nebulosity.
46	20 53 31	47 7	1 8	3 18	3,7	Suspected nebulosity joining to plainly visible diffused nebulosity.
47	21 0 26	76 3	0 44	2 46	2,0	Affected.
48	21 29 27	80 8	0 30	2 15	1,1	Much affected.
49	21 42 16	68 57	0 29	2 36	1,2	Affected.
50	22 52 36	64 47	0 29	2 47	1,3	Much affected.
51	22 53 6	64 47	0 42	2 47	1,9	Affected.
52	22 55 29	61 15	0 28	2 37	1,2	A little affected.

In looking over this table, it may be noticed that I have inserted several nebulosities that were only suspected. Had I been less scrupulous at the time of observation, the word suspected would generally have been omitted; for with this nebulosity, as well as with the great number of nebulæ that in my catalogues are marked suspected, I have almost without exception found, in a second review, that the entertained suspicion was either fully confirmed, or that, without having had any previous notice of the former observation, the same suspicion was renewed when I came to the same place again.

When these observations are examined with a view to improve our knowledge of the construction of the heavens, we see in the first

place that extensive diffused nebulosity is exceedingly great indeed; for, the account of it, as stated in the table, is 151,7 square degrees; but this, it must be remembered, gives us by no means the real limits of it, neither in the parallel, nor in the meridian; moreover, the dimensions in the table give only its superficial extent; the depth or third dimension of it may be far beyond the reach of our telescopes; and when these considerations together are added to what has been said in the foregoing article, it will be evident that the abundance of nebulous matter diffused through such an expansion of the heavens must exceed all imagination.

By nebulous matter I mean to denote that substance, or rather those substances which give out light, whatsoever may be their nature, or of whatever different powers they may be possessed.

Another remark of equal importance arises from the consideration of the observed nebulosities. By the account of the table we find that extreme faintness is predominant in most of them; which renders it probable that our best instruments will not reach so far into the profundity of space, as to see more distant diffusions of it. In No. 44 of the table, we have an instance of faint milky nebulosity, which, though pretty bright in some places, was completely lost from faintness in others; and No. 46 confirms the same remark. It has also been already mentioned in the first article, that the nebulosity in V. 14 was brighter in three or four places than in the rest. The stars also of the milky way which were scattered over it, and were generally very small, appeared with a brilliancy that will admit of no comparison with the dimness of the brightest nebulosity. In consequence of this, we may already surmise that the range of the visibility of the nebulous matter is confined to very moderate limits.

3. *Of Nebulosities joined to Nebulæ.*

The nature of diffused nebulosity is such that we often see it joined to real nebulæ; for instances of this kind we have the fourteen following objects*.

The account of the three first nebulæ being shortened in the catalogue, I give it here more at length.

* See I. 81, 207, 214. IV. 41. V. 32, 35, 37, 44, 51, 52. *Connoissance des Temps* 17, 42, 64, 78.

No. 81 in the first class is "A considerable bright and large ne-"bula. Its nebulosity is of the milky kind, and a small part of it "is considerably brighter than the rest. The greatest extent of "the milkiness is preceding the bright part, and the termination of "it is imperceptible." To No. 207 should be added, "It seems "to join to imperceptible nebulosity on the south preceding side;" and to No. 214, "It terminates abruptly to the north and is dif-"fused to the south." See fig, 2.

No. 42 of the *Connoissance* is the great nebula in the constellation of Orion discovered by Huyghens. This highly interesting object engaged my attention already in the beginning of the year 1774, when viewing it with a Newtonian reflector I made a drawing of it, to which I shall have occasion hereafter to refer; and having from time to time reviewed it with my large instruments, it may easily be supposed that it was the very first object to which, in February 1787, I directed my forty feet telescope. The superior light of this instrument showed it of such a magnitude and brilliancy that, judging from these circumstances, we can hardly have a doubt of its being the nearest of all the nebulæ in the heavens, and as such will afford us many valuable informations. I shall however now only notice that I have placed it in the present order because it connects in one object the brightest and faintest of all nebulosities, and thereby enables us to draw several conclusions from its various appearance.

The first is that the extensive diffused nebulosities contained in the objects of the preceding articles are of the same nature with the nebulosity in this great nebula; for when we pursue it in its extensive course it assumes precisely the same appearance as the before-mentioned diffused nebulosities.

The second consequence we may draw from the circumstance of its containing both the brightest and faintest nebulosity joined in one object, is a confirmation of an opinion already conceived in the second article, namely, that the range of the visibility of nebulous matter is what may be called very limited. The depth of the nebula may undoubtedly be exceedingly great, but when we consider that its greatest brightness does not equal that of small telescopic stars, as may be seen by comparing four of them situated within the inclosed darkness of the nebula, and several within its brightest

appearance, with the intensity of the nebulous light; it cannot be expected that such nebulosities will remain visible when exceedingly farther from us than this prime nebula: the ratio of the known decrease of light will not admit of a great range of visibility within the narrow limits whereby this shining substance can affect the eye.

From this argument a secondary conclusion may be drawn, which adds to what has already been said in the foregoing article, namely, that if our best telescopes cannot be expected to reach the nebulous matter, which by analogy we may suppose to be lodged among the very small stars plainly to be seen by them; the actual quantity of its diffusion may still farther exceed even the vast abundance of it already proved to exist. A nebulous matter, diffused in such exuberance throughout the regions of space, must surely draw our attention to the purpose for which it probably may exist; and it must be the business of a critical inquirer to attend to all the appearances under which it will be exposed to his view in the following observations.

4. *Of detached Nebulosities.*

The nebulosities of the preceding articles are not restricted to an extensive diffusion; we meet with them equally in detached collections; I shall only mention the following six *.

V. 21 consists of "A broad faint nebulosity extended in the " form of a parallelogram with a short ray from the preceding " corner towards the south. The nebulosity is nearly of an equal " brightness throughout the parallelogram, which is about 8′ long " and 5 or 6′ broad, but ill defined." See Fig. 3, *a*, *b*, *c*.

5. *Of milky Nubulæ.*

When detached nebulosities are small we are used to call them nebulæ, and it is already known from my catalogues that their number is very great. It will therefore be sufficient to refer only to a few, of which the nebulosity is of the milky kind †.

No. 9 in the 5th class is "A large, extended, broad, faint ne- " bula; its nebulosity, like that of the preceding one (which is De

* See I. 92. V. 21, 26, 36, 41, 42.

† See I. 204. III. 116. IV. 7, 20, 30. V. 9, 25.

"la Caille's last but one in the catalogue does Nebuleuses du Ciel "Austral)* is of the milky kind."

The only purpose for which the nebulæ of these two classes have been placed in this connection, is to show that large detached nebulosities, whatever may be their appearance, as well as those nebulæ expressly called milky, partake of the general nature of the diffused nebulous matter, pointed out in the preceding articles.

6. *Of milky Nebulæ with Condensation.*

In looking at the beautiful nebula in Orion; to which I refer, because every common good telescope will show it sufficiently well for the present purpose; we perceive that it is not equally bright in all its parts, but that its light is more condensed in some places than in others. The idea of condensation occurs so naturally to us when we see a gradual increase of light, that we can hardly find a more intelligible mode of expressing ourselves than by calling it condensed. The numerous instances that will be given hereafter of nebulæ that have this kind of condensation, renders it unnecessary to refer to more than the following four †.

The first of these, No. 11 in the first class, is "A bright nebula "of some extent, although not very large. It is of an irregular "figure, and the greatest brightness lies towards the middle. The "whitishness of this nebula is of the milky kind." See figure 4.

By attending to the circumstances of the size and figure of this nebula, we find that we can account for its greater brightness towards the middle in the most simple manner by supposing the nebulous matter of which it is composed to fill an irregular kind of solid space, and that it is either a little deeper in the brightest place, or that the nebulosity is perhaps a little more compressed. It is not necessary for us to determine at present to which of these causes the increase of brightness may be owing; at all events it cannot be probable that the nebulous matter should have different powers of shining such as would be required independent of depth or compression.

---

* See Connoissance des Temps for 1784, page 272.

† See I. 11, 84. III. 457. IV. 12.

7. *Of Nebulæ which are brighter in more than one place.*

It is not an uncommon circumstance that the same nebula is brighter in several different places than in the rest of its compass. The following six are of this sort *.

No. 213 in the first class is "A very brilliant and considerably "large nebula, extended in a direction from south preceding to "north following. It seems to have three or four bright nuclei." See fig. 5.

From this construction of the nebula, we may draw some additional information concerning the point which was left undetermined in my last article; for since there it was proposed as an alternative, that the nebulous matter might either be of a greater depth or more compressed in the brightest part of the nebula, then under consideration, we have now an opportunity to examine the probability of each case. If here the appearance of several bright nuclei is to be explained by the depth of the nebulous matter, we must have recourse to three or four separate very slender and deep projections, all situated exactly in the line of sight; but such a very uncommon arrangement of nebulous matter cannot pretend to probability; whereas a moderate condensation, which may indeed be also accompanied with some little general swelling of the nebulous matter about the places which appear like nuclei, will satisfactorily account for their superior brightness.

The same method of reasoning may be as successfully applied to explain the number of unequally bright places in the diffused nebulosities which have been described in the 1st, 2d, and 3d articles. For instance, in the branching nebulosity V. 14, we find three or four places brighter than the rest—in the nebulosity No. 44, of the table we have places of different brightness. In the nebula of Orion, there are many parts that differ much in lustre; and in V. 37 of the same article I found, by an observation in the year 1790, the same variety of appearance. In all these cases a proportional condensation of the nebulous matter in the brighter places will sufficiently account for their different degree of shining.

This way of explaining the observed appearances being admitted, it will be proper to enter into an examination of the probable cause

* See I. 165, 213, 261. II. 297, 406. III. 49.

of the condensation of the nebulous matter. Should the necessity for such a condensing cause be thought to be admitted upon too slight an induction, a more detailed support of it will hereafter be found in the condition of such a copious collection of objects, as will establish its existence beyond all possibility of doubt*.

Instead of inquiring after the nature of the cause of the condensation of nebulous matter, it would indeed be sufficient for the present purpose to call it merely a condensing principle; but since we are already acquainted with the centripetal force of attraction which gives a globular figure to planets, keeps them from flying out of their orbits in tangents, and makes one star revolve around another, why should we not look up to the universal gravitation of matter as the cause of every condensation, accumulation, compression, and concentration of the nebulous matter? Facts are not wanting to prove that such a power has been exerted; and as I shall point out a series of phænomena in the heavens where astronomers may read in legible characters the manifest vestiges of such an exertion, I need not hesitate to proceed in a few additional remarks on the consequences that must arise from the admission of this attractive principle.

The nebula, for instance, which has been described at the beginning of this article, as containing several bright nuclei, has probably so many predominant seats of attraction, arising from a superior preponderance of the nebulous matter in those places; but attraction being a principle which never ceases to act, the consequence of its continual exertion upon this nebula will probably be a division of it, from which will arise three or four distinct nebulæ. In the same manner its operation on the diffused nebulosities that have many different bright places, will possibly occasion a breaking-up of them into smaller diffusions and detached nebulæ; but before I proceed with conjectures, let us see what observations we have to give countenance to such expectations.

8. *Of double Nebulæ with joined Nebulosity.*

In addition to the instances referred to in the preceding article, of

* See Article 24.

nebulæ that have more than one centre of attraction, I give the following list of what may be called double nebulæ *.

The 316th nebula in the second class to which in the catalogue is joined the 317th, consists of "two small faint nebulæ of an equal "size within 1′ of each other. Each has a seeming nucleus, and "their apparent nebulosities run into each other. Their relative "position is in a direction from south preceding to north following." See Fig. 6, *a* and *b*.

Each of the fifteen objects referred to contains two nuclei or centers of attraction, and if the active principle of condensation carries on its operation, a division of their at present united nebulosities must, in the end, be the consequence. I have given two figures for the same double nebulæ. For although the nebulosities of figure *b*, when seen in the direction of the dotted lines will appear to run together, they may nevertheless be at some small distance from each other; but the same cause which will bring on a separation of it in figure *a*, will also make two distinct nebulæ of figure *b*.

With regard to their being double nebulæ, it may be objected that this double appearance may be a deception; and indeed if this were a double star, instead of a double nebula, there might be some room for such a surmise. But on two accounts the case is very different. In the first place, we have not nebulæ without number at all distances to which we might have recourse, in supposing one to be far behind the other, as we have stars behind stars to produce an appearance of their being double. In the next; if what has been said of the confined range of the visibility of the nebulous matter be recollected, especially where it is so faint as in the double nebula which has been described, we cannot harbour an idea that the two objects of which it is composed are very far asunder. Add to this their great resemblance in size, in faintness, in nucleus, and in their nebulous appearance; from all which I believe it must be evident that their nebulosity has originally belonged to one common stock.

9. *Of double Nebulæ that are not more than two Minutes from each other.*

To add to the probability of the separation of nebulæ, we ought

* See I. 56, 176, 178, 193. II. 80, 271, 309, 316, 832. III. 45, 644. IV. 8, 28, *Connoiss.* 27, 51.

to have a considerable number of them already separated. The following twenty-three are completely divided, although not more than two minuets from one another *.

A description of II. 714 is "Two pretty bright nebulæ; they are "*both round*, small, and about 2′ from each other, in a meridional "*direction*.

Of III. 755 is "Two very faint, very small extended nebulæ "within $1\frac{1}{2}'$ from each other.

That all these nebulæ are really double, is founded on the reason already assigned in the last article. Then if we would enter into some kind of examination how they came to be arranged into their binary order, we cannot have recourse to a promiscuous scattering, which by a calculation of chances can never account for such a peculiar distribution of them. If, on the contrary, we look to a division of nebulous matter by the condensing principle, than every parcel of it, which had more than one preponderating seat of attraction in its extent, must in the progress of time have been divided.

No doubt can be suggested on account of the great length of time such a division must have taken up, when we have an eternity of past duration to recur to.

10. *Of double Nebulæ at a greater distance than 2′ from each other.*

It may well be supposed that more than one attractive center would not be so frequent a case in small distances, as in nebulosities of a more extended compass; accordingly we find that separated nebulæ at more than 2′ from each other are much more numerous. The following 101 double nebulæ referred to will confirm this statement *.

---

* *See* I. 116, 190, 197, II. 8, 28, 57, 111, 178, 450, 714. III. 92, 228, 280, 591, 687, 719, 755, 855, 886, 943, 952, 959, 967.

* See I. 28, 36, 90, 145. II. 17, 44, 55, 61, 74, 84, 85, 115, 118, 121, 139, 153, 167, 219, 228, 233, 333, 388, 426, 429, 455, 518, 546, 550, 580, 614, 679, 684, 692, 751, 764, 787, 789, 841, 842, 865, 868, III. 9, 15, 35, 44, 51, 62, 97, 117, 121, 127, 129, 138, 154, 159, 162, 166, 167, 172, 196, 199, 210, 216, 231, 250, 277, 306, 323, 335, 344, 351, 377, 402, 404, 407, 416, 422, 431, 511, 546, 551, 572, 574, 592, 629, 635, 657, 678, 707, 758, 781, 798, 800, 802, 807, 869, 897, 917, 957, 959, 974.

No. 36 and 37 in the first class are "Two small bright nebulæ, "both a little extended."

No. 74 and 75 in the second class are "Two pretty bright nebu- "læ; the preceding of them is almost round; the following very "much extended in length; they are not far from the same paral- "lel, and about 8 or 10′ distant from each other."

No. 127 and 128 in the third class are, "Two extremely faint ne- "bulæ, about 3′ from each other, and nearly in the same parallel. "The second is a very little brighter than the first, and is of an "irregular round figure."

It is remarkable that in the description of all these 101 nebulæ, there are not more than five or six which differ so much in brightness from one another, that we could suppose them to be at any considerable different distance from us; and equal brightness or faintness runs through them all in general; but supposing that any two nebulæ should even differ as much from one another, as the set of the first class which has been described, is different from the faintness of the last described set, yet this would not nearly amount to the difference in the brightness of one part of the nebula in Orion from that of another of the same nebula.

11. *Of treble, quadruple, and sextuple Nebulæ.*

If it was supposed that double nebulæ at some distance from each other would frequently be seen, it will now on the contrary be admitted that an expectation of finding a great number of attracting centers in a nebulosity of no great extent is not so probable; and accordingly observation has shown that greater combinations of nebulæ than those of the foregoing article are less frequently to be seen. The following list however contains 20 treble, 5 quadruple, and 1 sextuple, nebulæ of this sort *.

Among the treble nebulæ there is one, namely, V. 10, of which the nebulosity is not yet separated. "Three nebulæ seem to join "faintly together, forming a kind of triangle; the middle of which "is less nebulous, or perhaps free from nebulosity; in the middle

* See *treble nebulæ*. I. 17. II. 50, 123, 141, 171, 215, 392, 447. III. 65, 94, 117, 156, 300, 358, 382, 592, 873, 900, 945. V. 10.
Quadruple. II. 482, 568. III. 356, 358, 562.
Sextuple. III. 391.

"of the triangle is a double star of the 2d or 3d class; more faint "nebulosities are following."

Among the quadruple nebulæ we have III. 358. "Four nebulæ, "all within three minutes. The largest is faint and small; the "other three are less and fainter. They form a small quartile, the "largest being the most north of the preceding side."

"The nebulæ which form the sextuple one are all very faint "and very small: they take up a space of more than 10 or 12 "minutes."

12. *Of the remarkable Situation of Nebulæ.*

The number of compound nebulæ that have been noticed in the foregoing three articles being so considerable, it will follow, that if they owe their origin to the breaking up of some former extensive nebulosities of the same nature with those which have been shown to exist at present, we might expect that the number of separate nebulæ should far exceed the former, and that moreover these scattered nebulæ should be found not only in great abundance, but also in proximity or continuity with each other, according to the different extents and situations of the former diffusions of such nebulous matter. Now this is exactly what by observation we find to be the state of the heavens.

In the following seven assortments we have not less than 424 nebulæ; some of them of unascertained size, figure, or condensation; and the rest with only the first of these three essential features recorded.

The reason for not having a more circumstantial account of such a number of objects, is that they crowded upon me at the time of sweeping in such quick succession, that of sixty-one I could but just secure the place in the heavens, and of the remaining three hundred and sixty-three, I had only time to add the relative size*.

---

* See *sixty-one nebulæ*. II. 30, 66, 68, 70, 109, 114, 117, 125, 138, 170, 174, 176, 345, 361, 390, 391, 496, 499, 541, 542, 543, 572, 573, 629, 631, 806, 898. III. 28, 26, 31, 33, 39, 41, 42, 89, 103, 189, 193, 205, 332, 353, 363, 364, 365, 390, 413, 432, 481, 483, 482, 484, 485, 669, 670, 705, 796, 819, 930, 934, 936. *Connoiss.* 84.

Ten extremely small nebulæ. III. 98, 108, 194, 195, 230, 238, 297, 526, 545, 639.

One hundred and thirty-six very small nebulæ. II. 22, 64, 67, 72, 91, 93, 287, 354, 367, 464, 497, 527, 544, 640, 641, 675, 720, 724, 739, 876. III.

Neither of the nebulæ in these seven divisions will require a description, as the title of each assortment contains all that has been ascertained about them; but their number and situation, especially when added to those that will be contained in the following articles, completely supports what has been asserted, namely, that the present state of the heavens presents us with several extensive collections of scattered nebulæ, plainly indicating by their very remarkable arrangement, that they owe their origin to some former common stock of nebulous matter.

To refer astronomers to the heavens for an inspection of these and the following nebulæ, would be to propose a repetition of more than eleven hundred sweeps to them, but those who wish to have some idea of the nebulous arrangements may consult Mr. Bode's excellent Atlas Cœlestis. A succession of places where the nebulæ of my catalogues are uncommonly crowded, will there be seen be-

---

6, 13, 22, 24, 34, 37, 38, 104, 111, 140, 164, 166, 186, 190, 237, 247, 255, 283, 285, 302, 303, 304, 309, 315, 317, 319, 325, 326, 333, 338, 339, 343, 354, 385, 386, 387, 389, 398, 411, 412, 421, 425, 430, 433, 435, 437, 443, 444, 453, 459, 460, 467, 470, 501, 507, 509, 525, 539, 544, 578, 579, 607, 618, 623, 625, 634, 638, 640, 641, 645, 650, 652, 659, 666, 702, 704, 708, 716, 718, 731, 733, 738, 762, 766, 775, 787, 788, 789, 799, 803, 809, 827, 831, 833, 836, 837, 838, 839, 848, 849, 866, 875, 883, 884, 894, 895, 905, 912, 913, 919, 956, 960, 961, 962, 965, 966.

Forty-two not very small nebulæ. I. 119. II. 65, 73, 100, 163, 248, 327, 352, 375, 382, 472, 606, 639, 765, 821, 838. III. 17, 30, 249, 281, 321, 327, 366, 375, 504, 548, 615, 628, 647, 660, 667, 698, 712, 715, 734, 751, 773, 774, 840, 850, 941. *Connois.* 89.

One hundred and seven small nebulæ. I. 25, 123. II. 18, 42, 46, 60, 71, 92, 94, 169, 264, 294, 324, 343, 350, 351, 316, 363, 374, 379, 381, 395, 396, 397, 398, 441, 493, 512, 529, 530, 539, 577, 578, 678, 710, 743, 778, 779, 794, 800. III. 25, 48, 57, 59, 60, 69, 74, 192, 206, 235, 243, 308, 328, 329, 334, 337, 350, 380, 420, 446, 458, 462, 464, 475, 478, 502, 516, 517, 529, 550, 588, 611, 651, 661, 664, 668, 721, 722, 723, 729, 761, 763, 769, 779, 780, 794, 797, 814, 826, 833, 841, 843, 861, 880, 881, 894, 915, 924, 925, 926, 927, 928, 939, 950, 951, 954, 969.

Fifty-eight pretty large nebulæ. I. 22, 24, 85, 169, 283. II. 34, 83, 107, 119, 137, 146, 292, 342, 358, 362, 366, 380, 383, 384, 385, 386, 387, 419, 498, 638, 652, 670, 713, 745, 801, 844, 862, 903, 905. III. 14, 18, 40, 70, 75, 76, 102, 213, 261, 279, 318, 340, 367, 372, 374, 415, 454, 473, 503, 543, 599, 662, 790, 970.

Ten large nebulæ. II. 106, 120, 175, 176. III. 28, 361, 440, 480. V. 6. *Connois.* 58.

ginning over the tail of Hydra, and proceeding to the southern wing, the body and the northern wing of Virgo, Plate 14. Then to Coma Berenices, Canes venatici, and the preceding arm of Bootes, Plate 7. A different branch goes from Coma Berenices to the hind legs of Ursa major. Another branch passes from the wing of Virgo to the tail and body of Leo, Plate 8.

It will not be necessary to point out many other smaller collections which may be found in several plates of the same Atlas.

On the other hand, a very different aspect of the heavens will be perceived when we examine the following constellations. Beginning from the head of Capricorn, Plate 16, thence proceeding to Antinous, to the tail of Aquila, Plate 9, to Ramus Cerberus, and the body of Hercules, Plate 8, to Quadrans Muralis, Plate 7, and to the head of Draco, Plate 3. We may also examine the constellations of Auriga, Lynx, and Camelopardalus, Plate 5.

In this second review, it will be found that here the absence of nebulæ is as remarkable, as the great multitude of them in the first mentioned series of constellations.

13. *Of very narrow long Nebulæ.*

In order to advance in our knowledge of the condition of the nebulous matter, we may investigate the form of its expansion by the figure of the nebulæ that have been observed. The following five are particular instances of some that were much extended in length, but very little in breadth *.

No. 254 in the 3d class is " A very faint nebula, extended from " north preceding to south following. It is about 5′ long and less " than ½ minute broad." See fig. 7.

The expansion of the nebulous matter in general may be considered as consisting of three dimensions; these may all be either nearly equal, or one of them may be much less than the other two; or the extent of two of them may be very inferior to that of the third. The nebulæ which have now been referred to exclude a nebulosity of three nearly equal dimensions, which can never be seen under less than two of them. When two of the dimensions of the nebulous matter are nearly equal, one of them may indeed be only visible; but then the chance that the other should be exactly

* See I. 23, 206. III. 254, IV. 72. V. 20.

parallel to the line of sight, is by no means favourable. The most plausible way of accounting for the apparent figure of these nebulæ is, therefore, to admit that the expansion of the nebulosity consists indeed of a very narrow length, and not much depth. This form when ascribed to nebulous matter, is sufficiently uncommon for us to expect to see many nebulæ of the figure of extended rays.

14. *Of extended Nebulæ.*

This class of nebulæ, which are chiefly extended in length, but at the same time have a considerable breadth, is very numerous. I have divided the nebulæ it contains, which are 284, into five assortments as follows *.

II. 514 is " A faint nebula extended from south preceding to " north following; it is about 2′ long and 1′ broad." See fig. 8.

III. 523 is " A very faint nebula extended from south preceding to north following; it is 3 or 4′ long and nearly 3′ broad."

---

* See *one hundred and sixty-one extended nebulæ of various small sizes.*— I. 80, 89, 194, 202, 234. II. 14, 53, 72, 82, 108, 133, 145, 164, 206, 260, 262, 278, 280, 305, 348, 414, 436, 437, 486, 507, 520, 522, 574, 585, 611, 627, 638, 642, 649, 668, 682, 696, 700, 723, 731, 742, 772, 785, 786, 802, 809, 810, 826, 830, 831, 835, 837, 844, 847, 853, 859, 885. III. 4, 23, 56, 58, 65, 66, 73, 79, 82, 100, 110, 132, 183, 218, 225, 236, 241, 242, 244, 248, 258, 265, 305, 313, 314, 316, 342, 347, 348, 355, 369, 370, 406, 410, 419, 427, 429, 441, 442, 445, 450, 479, 487, 490, 494, 496, 499, 510, 514, 515, 520, 521, 528, 554, 557, 567, 569, 570, 586, 598, 599, 601, 612, 613, 619, 646, 649, 653, 677, 681, 682, 713, 714, 727, 730, 732, 752, 767, 771, 778, 783, 792, 804, 806, 808, 811, 812, 813, 826, 832, 845, 846, 874, 885, 892, 904, 914, 920, 929, 932, 942, 948, 949, 973.

Sixty-two extended nebulæ of various large sizes. I. 14, 20, 76, 141, 189, 212, 215, 220, 253. II. 3, 17, 23, 63, 113, 126, 134, 147, 152, 156, 165, 188, 221, 235, 251, 300, 326, 335, 344, 355, 378, 407, 453, 492, 525, 548, 566, 579, 595, 607, 619, 620, 671, 687, 703, 750, 755, 762, 799. III. 253, 282, 290, 346, 414, 492, 498, 508, 610, 639, 740, 766, 776, 921.

Thirty-one extended nebulæ from ¾ to 2′ long. II. 150, 181, 222, 237, 365, 479, 510, 514, 535, 582, 624, 654, 655, 674, 763, 798, 807, 829, 881, 897, 899, 901. III. 203, 368, 506, 556, 620, 648, 692, 906, 907.

Twenty-four extended nebulæ from 2 to 5′ long. I. 94, 174, 201. II. 227, 284, 291, 402, 432, 490, 536, 558, 600, 664, 747, 784, 900. III. 362, 523, 524, 553, 603, 710, 711, 717.

Six extended nebulæ from 5 to 15′ long. I. 134, 155, 285. II. 824. V. 5, 23.

I. 134 is "A considerably bright nebula, 7 or 8 minutes long "and about 3′ broad."

The considerable breadth of these nebulæ, although chiefly extended in length, proves that two of the dimensions of the nebulous matter, namely, the breadth and depth, are probably not very different; for if the depth, which is the dimension we do not see, should be equal to the length, the chance of its being out of sight is not sufficiently probable to happen very frequently. It is therefore to be supposed that the extension in length is really the greatest; for as we actually see it under this form, we are assured that it is at least as long as it appears, whereas one of the other dimensions, if not both, must certainly be less than the length. This kind of expansion admits of the utmost variety of lengthened form and position; and from the great number of nebulæ to which I have referred, the existence of such nebulosities is fairly to be deduced.

15. *Of Nebulæ that are of an irregular Figure.*

Among the various figures that may be seen in nebulæ we have a great many that are of an irregular appearance; I have divided the following ninety-three into two assortments *.

I. 61 is "A very bright small nebula north following a star of "the 9th magnitude. It is of an irregular figure." See fig. 9.

II. 289 is "A faint pretty large nebula; it is of an irregular "triangular figure."

By calling the figure of a nebula irregular, it must be understood that I saw no particular dimension of it sufficiently marked to deserve the name of length; for had there been such a distinction, its extension in the longitudinal direction would have been recorded, or, as it frequently happened, for want of time, the nubula would shortly have been called extended. From this consideration it

---

* *See sixty-one irregular nebulæ of various small sizes.* I. 61, 284. II. 185, 242, 259, 274, 281, 306, 339, 415, 445, 586, 597, 601, 605, 647, 744, 761, 834, 886, 893, 907. III. 12, 83, 191, 259, 273, 287, 301, 310, 456, 465, 485, 486, 493, 495, 533, 535, 537, 555, 581, 582, 605, 642, 663, 675, 699, 701, 724, 735, 795, 817, 834, 847, 851, 868, 879, 893, 963, 976, 977.

Thirty-two irregular nebulæ of various large sizes. I. 138, 246, 248, 282. II. 43, 81, 149, 289, 346, 349, 360, 421, 467, 468, 495, 587, 651, 681, 711, 749, 756, 804, 877. III. 137, 257, 274, 463, 683, 695, 765, 911, 938,

follows, that the nebulous matter which assumes an irregular figure when seen in a telescope, cannot be very different in two of its dimensions; and this leaving the third entirely undetermined, it may be of greater, equal, or less extent than either of the other two. But to be greater or less than the dimensions that were seen it would require the particular situation of the third dimension in either case to be in the direction of the line of sight, which is so far at least improbable, that we may fairly suppose the unseen dimension not to differ much from either of the former two.

16. *Of Nebulæ that are of an irregular round Figure.*

The apparent figure of the nebulæ contained in the foregoing articles has already assisted me in a great measure to assign the expanded form of the nebulous matter of which they consist. The irregular round appearance of the following fifty-five nebulæ however, being of a much more marked description than the former, will lead to more decisive conclusions. I have divided them into three assortments *.

No. 177 in the third class is "A very faint nebula of an irregular "round figure, about 2 or 3 minutes in diameter." See fig. 10.

The appearance of an irregular round figure necessarily requires that the extent of two dimensions of the nebulous matter should be nearly equal in every direction at right angles to each other. The unseen dimensions may certainly be longer or shorter than the visible irregular diameter; but then it must be absolutely extended centrally in the line of sight, which is a condition that has no probability in its favour; and the greater the number is, of such nebulæ, the less is the probability that the form of the nebulous matter should be irregularly cylindrical, or conical. For, except an irregular cylinder or cone, placed in the particular required situation,

* See *twenty-eight nebulæ of an irregular round figure of various small sizes.* I. 231. II. 97, 191, 243, 254, 273, 336, 560, 758, 895, 896. III. 208, 224, 311, 474, 566, 600, 614, 621, 673, 674, 688, 728, 784, 813, 835, 931, 955.

Twenty-one nebulæ of an irregular round figure of various large sizes. I. 69, 108, 161. II. 197, 240, 494, 513, 537, 538, 552, 685, 727, 872, 890. III. 426, 447, 558, 862, 876. V. 7. *Connoiss.* 70.

Six nebulæ of an irregular round figure of a mean diameter from 1 *to* 5′. III. 131, 177. 223, 261, 542, 617.

no expansion of the nebulous matter but an irregular globular one can be the cause of the irregular round figure of the above-mentioned nebulæ. Then since the irregular globular form has this advantage above the cylindrical and conical figure, that it will answer the required end in any situation whatsoever, it is certainly that which ought to be admitted as the cause of the observed appearance.

This method of reasoning upon the form of the nebulous matter from the observed figure of nebulæ, will lead us a step farther than it might have been supposed. For granting it to be highly probable, that the appearance of irregular round nebulæ is owing to so many irregular globular expansions of nebulous matter, it will be necessary to direct our attention to the cause which has formed this matter into such masses. To ascribe an highly improbable event to chance, is not philosophical; especially as a forming cause offers itself to our view, when we direct an eye to the globular figure of the planets and satellites of the solar system.

17. *Of round Nebulæ.*

From what has been said, it appears that the figure of nebulæ is a subject of more interest than mere curiosity. The following fifty-seven were observed to be round, and I give them here in four assortments *.

As the title of each sort gives all that is necessary for the present purpose relating to the various sizes of round nebulæ, a description of one of the last will be sufficient. The observation of I. 269 says, that it is " A considerably bright round nebula of about one minute in diameter." See fig. 11.

The arguments which I have given in the foregoing article, where only nebulæ of an irregular round figure were considered, need not be repeated when a regular circular form is presented to our view;

* See *three round nebulæ.* III. 381, 511, 758.

Forty-one round nebulæ of various small sizes. I. 275. II. 54, 218, 223, 225, 329, 659, 760, 803. III. 11, 50, 78, 94, 95, 96, 149, 150, 180, 181, 209, 221, 222, 295, 371, 451, 477, 505, 622, 631, 671, 684, 726, 760, 800, 801, 810, 842, 888, 909, 946, 971.

Ten round nebulæ of various large sizes. I. 7, 124, 252. II. 19, 481, 889. III. 54, 77, 112, 452.

Three round nebulæ from 1 *to* 6′ *in diameter.* I. 269. II. 593. V. 16.

for the additional number of nebulæ, and the regularity of their figure, are both greatly in favour of a conclusion, that the mass of the nebulous matter which occasions their appearance must be of a globular form.

In the last article I have only directed our attention to the cause of this very particular construction; but from the observations of the nebulæ above referred to, we may now more confidently assign the attraction of gravitation as the principle which has drawn the nebulous matter towards a centre, and collected it into a spherical compass.

I have already shown that the same principle appears to be the cause of the condensation of the nebulous matter in the bright places of the nebulæ that shine with unequal degrees of light in the different parts of their extent*; and a concurrence of arguments established upon very different foundations cannot fail to give additional weight to the reasonings by which they are supported.

18. *Of Nebulæ that are remarkable for some particularity in Figure or Brightness.*

Among the nebulæ, which I have described as of an irregular figure, the following might have been inserted; but the real form of the nebulous matter of which they consist is probably as irregular as the figure or brightness of the nebulæ themselves. I have arranged thirty-five of them into three assortments †.

V. 19 is "A considerably bright nebula about 25′ long and 3′ "broad; its length is divided in the middle by a black division at "least three or four minutes long." See fig. 12.

The nebulous matter of this nebula is probably a ring in a very oblique position with respect to the line of sight.

II. 646 is "A pretty bright, large nebula, of an irregular figure: "it is unequally bright."

---

* See Article 7.

† See *two nebulæ of remarkable figure.* I. 286. V. 19.

Ten unequally bright nebulæ. I. 254. II. 200, 210, 422, 557, 591, 646. III. 142, 245, 534.

Twenty-three nebulæ that are brightest on one side. I. 113, 162. II. 26, 27, 136, 155, 313, 332, 364, 369, 370, 442, 506, 531, 555, 589, 623. III. 120, 153, 286, 676, 700. V. 22.

The inequality of its brightness in different parts may arise from unequal condensation, or from greater depth of nebulous matter.

II. 313 is "A pretty bright nebula, a little extended in the "parallel. The greatest brightness is towards the following side, "which is also the broadest; the preceding part being more like a "ray proceeding from it."

The irregular figure of these latter kind of nebulæ may be admitted to arise from the as yet imperfect concentration of a nebulous mass, in which the preponderating matter of it is not in the centre.

19. *Of Nebulæ that are gradually a little brighter in the middle.*

The investigation of the form of the nebulous matter in the 13, 14, 15, and 16th articles has been founded only upon the observed figure of nebulæ; and in the 17th article the globular form of this matter deduced from the round appearance of nebulæ, has been ascribed to the action of the gravitating principle. I am now entering upon an examination of nebulæ of which, besides their figure, I have also recorded the different degrees of light, and the situation of the greatest brightness with respect to their figure. These observations will establish the former conclusions by an additional number of objects, and by the decisive argument of their brightness, which points out a seat of attraction.

In the following four assortments are one hundred and fifty nebulæ, which all agree in being a little brighter in the middle. This increase of brightness must be understood to be always very gradual from the outside towards the middle of the nebula, whatever be its figure; and although this circumstance, for want of time, has often been left unnoticed in the observation, I am very sure that had the gradation of brightness been otherwise, it would certainly not have been overlooked*.

---

* See *Thirty-two nebulæ, the particular figure of which has not been ascertained, gradually a little brighter in the middle.* II. 201, 401, 424, 444, 457, 528, 532, 616, 617, 648, 673, 677, 736, 904. III. 90, 106, 148, 331, 436, 472, 489, 519, 596, 633, 654, 655, 656, 686, 854, 860, 869, 896, 978.

Twenty-four extended nebulæ, gradually a little brighter in the middle. II. 184, 192, 252, 285, 412, 478, 480, 565, 621, 688, 906. III. 141, 233, 449, 461, 468, 488, 532, 577, 736, 890. V. 8, 40, 50.

Twenty nebulæ of an irregular figure, gradually a little brighter in the

III. 853 is "A very faint small nebula; it is very gradually a "little brighter in the middle."

III. 488 is "A very faint extended nebula, near 3′ long, and "above 2′ broad; it is gradually a little brighter in the middle." Fig. 13.

II. 549 is "A very large and pretty bright nebula of an irregu-"lar figure; it is a little brighter in the middle." Fig. 14.

II. 812 is "A faint, small, round nebula; it is very gradually a "little brighter in the middle, and the increase of brightness begins "at a distance from the center." Fig. 15.

It is hardly necessary to say that the united testimony of so many objects can leave no doubt about the central seat of attraction, which in every instance of figure is pointed out to be in the middle.

The only remark I have to make, relates to the exertion of the condensing power, which in the case of these nebulæ appears to have produced but a very moderate effect. This may be ascribed either to the unshapen mass of nebulous matter which would require much time before it could come to some central arrangement of form either in length, or in length and breadth, or lastly in all its three dimensions. It may also be ascribed to the small quantity of the preponderating central attractive matter; or even to the shortness of its time of acting: for in this case millions of years perhaps are but moments.

20. *Of Nebulæ which are gradually brighter in the middle.*

By the general description of a nebula, when it is said to be gradually brighter in the middle, we are to understand that its light was observed to be obviously brighter about the center than in other parts. Had the nebulæ of this class been only a little brighter, or had they been much brighter in the middle, such additional ex-

---

middle. II. 213, 357, 403, 471, 487, 491, 524, 533, 594, 717, 729. III. 272, 428, 434, 626, 690, 857, 903, 947. V. 29.

Seventy-four round or nearly round nebulæ, gradually a little brighter in the middle. II. 7, 40, 102, 129, 131, 162, 190, 249, 258, 267, 276, 286, 290, 308, 320, 338, 428, 459, 474, 476, 477, 509, 516, 526, 602, 637, 699, 726, 737, 770, 780, 797, 811, 812. III. 62, 63, 94, 105. 121, 122, 123, 133, 162, 163, 252, 292, 296, 298, 330, 388, 409, 448, 466, 497, 522, 597, 608, 665, 680, 746, 750, 753, 818, 822, 823, 824, 858, 867, 889, 891, 903, 917, 918, 923.

pressions would certainly have been used; except where time would not allow to be more particular. I have sorted two hundred and twenty-three of these nebulæ like the foregoing, according to their figure, into four classes *.

II. 409 is "A pretty bright and pretty large nebula; it is very "gradually brighter in the middle."

I. 55 is "A considerably bright, extended nebula about 4′ long "and 2′ broad, in a meridional direction; it is gradually brighter "in the middle." Fig. 16.

I. 266 is "A considerably bright, and pretty large nebula, of an "irregular figure; it is gradually brighter in the middle." Fig. 17.

I. 98 is "A considerably bright, and pretty large round ne-"bula; it is brighter in the middle, the brightness diminishing "very gradually from the center towards the circumference." Fig. 18.

From the account of these nebulæ, we find again that all what has been said concerning the seat of the forming and condensing power of the nebulous matter, is abundantly confirmed by observation.

I have only to remark, that the exertion of the gravitating prin-

---

* See *Thirty-nine nebulæ of an unascertained figure, gradually brighter in the middle.* I. 19, 49, 264. II. 24, 49, 87, 88, 89, 90, 319, 337, 347, 368, 373, 409, 440, 515, 534, 590, 610, 634, 636, 672, 683, 830, 840, 856, 857, 858, 860, 861, 863. III. 275, 584, 587, 602, 872, 892, 935.

Fifty extended nebulæ gradually brighter in the middle. I. 1, 55, 62, 131, 199, 241, 259, 263, 279. II. 1, 10, 52, 77, 95, 132, 135, 157, 203, 205, 211, 253, 266, 302, 325, 405, 417, 508, 539, 545, 583, 592, 613, 625, 643, 656, 667, 697, 709, 730, 775, 880, 882. III. 246, 267, 589, 594, 864, 902. V. 4, 39.

Twenty-nine nebulæ of an irregular figure, gradually brighter in the middle. I. 95, 196, 227, 266. II. 36, 56, 96, 130, 226, 265, 295, 314, 353, 423, 433, 434, 475, 488, 553, 596, 657, 663, 690, 793, 819, 825, 887. III. 397, 500.

One hundred and five round, or nearly round nebulæ, gradually brighter in the middle. I. 5, 12, 54, 70, 98, 106, 120, 148, 168, 186, 211, 222, 229, 242, 245, 274. II. 50, 51, 128, 151, 158, 160, 161, 196, 208, 224, 247, 255, 256, 263, 275, 293, 307, 312, 330, 331, 533, 359, 376, 399, 408, 411, 435, 458, 461, 465, 511, 517, 523, 562, 567, 580, 588, 594, 614, 615, 622, 632, 633, 635, 662, 712, 719, 741, 769, 777, 792, 817, 818, 845, 851, 852, 865, 866, 873, 879, 883, 884, 888, 902. III. 2, 88, 107, 138, 139 220, 491, 527, 541, 709, 694, 739, 749, 825, 829, 865, 870 871, 882, 889, 900, 933, 937, 940, 972.

ciple in these nebulæ, is in a more advanced state than with those of the last article; and that the same conceptions which have already been suggested, namely, the original form of the nebulous matter; its quantity in the seat of the attracting principle; and the length of the time of its action, when properly considered, will sufficiently account for the present state of these nebulæ.

21. *Of Nebulæ that are gradually much brighter in the middle.*

The nebulous matter which appears under the various forms of the following four assortments, containing two hundred and two nebulæ, assumes now a more condensed aspect, than that under which it was seen in either of the two foregoing collections; and thus by its gradually greater compression, gives us a still more decisive indication of the central seat of attraction *.

II. 828 is "A pretty bright small nebula, very gradually much "brighter in the middle."

I. 101 is "A considerably bright pretty large nebula, extended "in the meridional direction, about 4′ or 5′ long; much brighter in "the middle." In the forty feet telescope I saw the very gradual

* See *Twenty-five nebulæ of unascertained figure, gradually much brighter in the middle.* I. 73, 121, 127, 140, 155, 181, 287. II. 35, 177, 187, 299, 439, 452, 540, 653, 658, 669, 686, 694, 795, 828, 855, 871. III. 863. *Connois.* 99.

Fifty-four extended nebulæ, gradually much brighter in the middle. I. 29, 31, 33, 35, 38, 53, 58, 64, 72, 82, 86, 92, 97, 101, 104, 125, 154, 157, 164, 184, 209, 233, 239, 274, 271, 277. II. 12, 13, 31, 37, 182, 212, 231, 282, 318, 416, 431, 463, 504, 604, 612, 626, 691, 701, 702, 704, 725, 753, 775, 875. III. 179, 198. V. 47. *Connois.* 49.

Nineteen nebulæ of an irregular figure, gradually much brighter in the middle. I. 10, 26, 59, 66, 109, 110, 114, 115, 219, 235, 237, 276. II. 2, 20, 438, 503, 734, 827. III. 299.

One hundred and four round or nearly round nebulæ, gradually much brighter in the middle. I. 8, 16, 21, 30, 42, 63, 65, 67, 68, 74, 79, 83, 87, 88, 100, 102, 105, 111, 112, 118, 129, 135, 136, 142, 144, 147, 150, 158, 159, 166, 171, 175, 182, 185, 216, 218, 221, 232, 238, 244, 257, 260, 265, 273, 278. II. 5, 11, 38, 69, 98, 148, 230, 236, 245, 250, 267, 269, 270, 277, 288, 292, 301, 303, 209, 311, 328, 418, 420, 446, 462, 466, 556, 561, 564, 575, 598, 632, 644, 645, 660, 666, 695, 707, 728, 738, 757, 767, 774, 782, 816, 823, 839, 854, 874. III. 250, 284, 512, 531, 624, 744, 859, 878. *Connois.* 59, 96.

increase of brightness towards the middle of its length; a longer extent of the nebula was also visible. Fig. 19.

I. 219 is "A very bright considerably large nebula of an "irregular figure, very gradually much brighter in the middle." Fig. 20.

I. 63 is "A bright round nebula of about one minute in diame-"ter; it is much brighter in the middle, and very faint towards the "border." Fig. 21.

The greater difference between the comparative brightness of the center, and the outward parts of these nebulæ, may certainly be ascribed to the same causes that have been considered in the two foregoing articles; but in the present case, and taking into the account that this is already a third step of condensation from a little brighter to brighter; then, to much brighter, there appears to be some foundation for supposing rather that this greater effect is produced by a longer time of the action of the attractive principle, than that it should arise merely from an original more favourable expansion of the nebulous matter.

22. *Of the Nebulæ that have a Cometic appearance.*

Among the numerous nebulæ I have seen, there are many that have the appearance of telescopic comets. The following are of that sort*.

I. 4 is "A pretty large cometic nebula of considerable bright-"ness; it is much brighter in the middle, and the very faint cheve-"lure is pretty extensive." Fig. 22.

By the appellation of cometic, it was my intention to express a gradual and strong increase of brightness towards the center of a nebulous object of a round figure; having also a faint chevelure or coma of some extent, beyond the faintest part of the light, gradually decreasing from the center.

It seems that this species of nebulæ contains a somewhat greater degree of condensation than that of the round nebulæ of the last article, and might perhaps not very improperly have been included in their number. Their great resemblance to telescopic comets, however, is very apt to suggest the idea, that possibly such small

* See *Seventeen cometic nebulæ.* I. 3, 4, 34, 217. II. 6, 15, 33, 59, 104, 153, 154, 241, 315, 404. III. 5, 21. *Connois.* 95.

telescopic comets as often visit our neighbourhood may be composed of nebulous matter, or may in fact be such highly condensed nebulæ.

23. *Of Nebulæ that are suddenly much brighter in the middle.*

From the third degree of visible condensation, I have in the 21st article intimated, that the length of the time of the action of the attracting principle, would explain the observed gradual accumulation of the nebulous matter. In the following eighteen nebulæ we may see a still more advanced compression of it, amounting almost to the appearance of a nucleus*.

II. 814 is "A small faint nebula, very suddenly much brighter "in the middle."

I. 39 is "A very bright nebula, extended from south-preceding "to north-following, about 4′ or 5′ long, and 3′ broad; it is much "brighter in the middle, but the brightness breaks off abruptly, so "as almost to resemble a nucleus." Fig. 23.

I. 256 is "A very bright pretty large nebula of an irregular "figure; it is suddenly much brighter in the middle." Fig. 24.

I. 99 is "A very bright, small round nebula; it is very suddenly "much brighter in the middle." Fig. 25.

From the appearance of these nebulæ, we see plainly that a progressive concentration of the nebulous matter has an existence; it is also remarkable that the condensation in long nebulæ inclines towards the shape of a nucleus, as well as in round ones, which can be ascribed only to the continued action of the attracting principle, tending to draw the nebulous extended expansion into a globular form.

A nucleus, to which these nebulæ seem to approach, is an indi cation of consolidation; and should we have reason to conclude that a solid body can be formed of condensed nebulous matter, the nature of which has hitherto been chiefly deduced from its shining

* See *One nebula of unascertained figure, suddenly much brighter in the middle*, II. 814.

Seven extended nebulæ, suddenly much brighter in the middle. I. 39, 91, 96, 200. II. 183, 505. *Connois.* 66.

Two nebulæ of an irregular figure, suddenly much brighter in the middle. I. 256. II. 521.

Eight round or nearly round nebulæ, suddenly much brighter in the middle. I. 99, 138. II. 410, 413, 698. III. 251, 685. *Connois.* 54.

quality, we may possibly be able to view it with respect to some other of its properties.

24. *Of round Nebulæ increasing gradually in brightness up to a Nucleus in the middle.*

It has already been proved, from the figure and central brightness of round nebulæ, that the nebulous matter of which they consist must be admitted to be of a globular form; but the following thirteen nebulæ lead me to a remark which not only applies to them, but to all the round nebulæ of the last five articles, which added to these amount to three hundred and twenty-one. They are not only round, but the gradual condensation from the circumference to the very center being of equal density of light at equal central distances, every ring or circle drawn round the center bears witness to the existence of a central attraction. For whatever may be the intensity of the ratio of the concentration at any given central distance, it follows, from the equality of brightness at the assigned distance, that no figure but a globular one can with any kind of probability explain the appearance; and that the concentration, as well as the figure, is produced by a general gravitation of the nebulous matter *.

I. 151 is "A considerably bright and considerably large, round "cometic nebula; it is very gradually much brighter in the middle, "with a nucleus in the center." Fig. 26.

From the description of these nebulæ, we find that an actual nucleus has been formed in the attracting center; and that consequently a certain degree of consolidation of the nebulous matter is highly probable; for, although the quality of shining only points out the existence of something that is luminous, yet from analogy we have reason to conclude that certain material substances must be present to produce the light we perceive; and that they must be opaque, may be inferred from every thing we know about shining substances.

25. *Of Nebulæ that have a Nucleus.*

It may be expected that some considerable change will take place in the appearance of a nebula after it has come to a certain

---

* See I. 2, 6, 132, 151, 173, 236, 272. II. 25, 189, 716, 864. III. 518. IV. 6.

degree of continued gradual condensation. We are as yet so little acquainted with the nature and distribution of this matter, that an application of mathematical calculations, founded on the attraction of gravitation, for want of data, cannot be applied in order to suggest to us what appearance might next be expected; I shall therefore proceed in a regular manner to give the observations, which shew what these appearances are, without entering into any theoretical discussions.

In the following two assortments we have forty nebulæ *.

Number 63 of the *Connoissance des Temps* is "A very bright "nebula, extending from north-preceding to south-following 9 "or 10′ long, and near 4′ broad; it has a very brilliant nucleus." Fig. 27.

I. 107 is "A very bright round nebula, about $1\frac{1}{2}$ minutes in "diameter; it has a bright nucleus in the middle." Fig. 28

The nuclei of these nebulæ, after what has been proved of the existence of a condensing power, I need not hesitate to ascribe to the longer continuance of its action, which appears to bring on a consolidation; and that this may be the consequence we may conclude, not only from the power of condensing, which argues a sufficient quantity of matter, but also from the quality of shining; for this proves that the substance which throws out the nebulous light is endowed with some other of the general qualities of matter besides that of gravitation.

A second remark I have to make is, that the opaque nature of the nebulous matter which was before inferred from analogy, is here supported by observation; for these consolidated nuclei have a considerable resemblance to the disks of planets; and if this matter consisted only of a luminous substance, the increase of light would probably far exceed their observed lustre: this being the case, the power of arresting light in its passage is an additional quality, very different from those which have already been mentioned, and seems to be analogous to properties which we know to belong to hard and solid bodies.

* See *Twenty-seven extended nebulæ, with a nucleus.* I. 43, 77, 126, 156, 176, 180, 208, 224, 240, 250, 253, 270, 280, 281. II. 238, 460, 759, 768, 796, 846, 849, 891. V. 18, 24, 48. *Connoiss.* 63, 101.

Thirteen round or nearly round nebulæ, with a nucleus. I. 107, 133, 139, 152, 167, 203, 225. II. 99, 501, 746, 754. III. 178. *Connoiss.* 90.

26. *Of extended Nebulæ that show the Progress of Condensation.*

When the nebulous matter is much extended in length, it appears from the following nebulæ, that with those which have a nucleus completely formed, the nebulosity on each side of it is comparatively reduced to a fainter state than it is in nebulæ of which the nucleus is apparently still in an incipient state. These faint opposite appendages to the nucleus I have in my observations called branches.

In some nebulæ there is also an additional small faint nebulosity of a circular form about the nucleus, and this I have called the chevelure. The following two assortments contain twenty-eight nebulæ of this kind *.

Number 65 of the *Connoissance* is " A very brilliant nebula ex-
" tended in the meridian, about 12′ long. It has a bright nucleus,
" the light of which suddenly diminishes on its border, and two op-
" posite very faint branches." Fig. 29.

I. 205 is " A very brilliant nebula, 5′ or 6′ long and 3′ or 4′
" broad; it has a small bright nucleus with a faint chevelure about
" it, and two opposite very extensive branches." Fig. 30.

The construction of these nebulæ is certainly complicated and mysterious, and in our present state of knowledge it would be presumptuous to attempt an explanation of it: we can only form a few distant surmises, which however may lead to the following queries. May not the faintness of the branches arise from a gradual diminution, of the length and density of the nebulous matter contained in them, occasioned by its gravitation towards the nucleus into which it probably subsides? Are not these faint nebulous branches joining to a nucleus, upon an immense scale, somewhat like what the zodiacal light is to our sun in miniature? Does not the chevelure denote that perhaps some of the nebulous matter still remaining in the branches, before it subsides into a nucleus, begins to take a spherical form, and thus assumes the semblance of a faint

---

* See *Twenty-three extended nebulæ with a nucleus and two opposite faint branches.* I. 9, 13, 15, 27, 32, 75, 136, 160, 163, 187, 193, 135, 263, 288, 290. II. 101, 650, 733. IV. 61. V. 43. Connois. 65, 83, 98.

Five with a nucleus, chevelure and branches. I. 194, 205, 219. V. 45. Connois. 94.

chevelure surrounding it in a concentric arrangement? And, if we may venture to extend these queries a little farther—will not the matter of these branches in their gradual fall towards the nucleus, when discharging their substance into the chevelure, produce a kind of vortex or rotatory motion? Must not such an effect take place, unless we suppose, contrary to observation, that one branch is exactly like the other; that both are exactly in a line passing through the center of the nucleus, by way of causing exactly an equal stream of it from each branch to enter the chevelure at opposite sides; and, this not being probable, do we not see some natural cause which may give a rotatary motion to a celestial body in its very formation?

27. *Of round Nebulæ that show the Progress of Condensation.*

When round nebulæ have a nucleus, it is an indication that they have already undergone a high degree of condensation. From their figure we are assured that the form of the nebulosity of which they are composed is now spherical, whatever may have been its original shape; and being surrounded by a chevelure, we may look upon its different evanescent degrees of faintness as a sign whereby to judge of the gradual progress of the consolidation of the nucleus. The following seventeen nebulæ are given in two assortments*.

IV. 23 is "A considerably bright nebula with a very bright nu-" cleus, and a chevelure about 3 or 4′ in diameter." Fig. 31.

III. 99 is "A small nebula with a pretty bright nucleus and very " faint chevelure; it is almost like a nebulous star." Fig. 32.

The chevelure of these nebulæ consists probably of the rarest nebulous matter, which not having as yet been consolidated with the rest, remains expanded about the nucleus in the shape of a very extended atmosphere; or it may be of an elastic nature, and be kept from uniting with the nucleus, as their elasticity causes the at-

* See *Fifteen round or nearly round nebulæ, with a nucleus and faint chevelure.* I. 40, 137, 226, 242, 251, 262. II. 321. III. 291, 373. IV. 23, 54, 56, 59, 76. *Connoiss.* 32.

Two nebulæ with a nucleus and chevelure resembling nebulous stars. II. 32. III. 99.

mospheres of the planets to be expanded about them. In this case we have another property of the nebulous substance to add to the former qualities of its matter.

With those nebulæ where this chevelure is uncommonly faint, and the nucleus very bright, the consolidation appears to have reached a still higher degree, and their resemblance to nebulous stars may lead to very interesting consequences.

28. *Of round Nebulæ that are almost of an uniform Light.*

The argument that the nebulous matter is in some degree opaque which is given in the 25th article, will receive considerable support from the appearance of the following nebulæ; for they are not only round, that is to say the nebulous matter of which they are composed is collected into a globular compass, but they are also of a light which is nearly of an uniform intensity, except just on the borders. I give these nebulæ in two assortments *.

Number 97 of the *Connoissance* is " A very bright, round ne- " bula of about 3′ in diameter; it is nearly of equal light through- " out, with an ill-defined margin of no great extent."

IV. 13 is " A pretty faint nebula of about 1′ diameter; it is per- " fectly round, and of an equal light throughout; and the edges of " it are pretty well defined." Fig. 33.

Admitting that these sixteen nebulæ are globular collections of nebulous matter, they could not appear equally bright, if the nebulosity of which they are composed consisted only of a luminous substance perfectly penetrable to light; at least this could not happen unless a certain artificial condensation of it were introduced, which can have no pretension to probability in its favour. Is it not rather to be supposed, that a certain high degree of condensation has already brought on a sufficient consolidation to prevent the penetration of light, which by this means is reduced to a superficial planetary appearance?

29. *Of Nebulæ that draw progressively towards a Period of final Condensation.*

In the course of the gradual condensation of the nebulous matter,

* See *Four from 2′ to 4′ in diameter.* IV. 50, 62, 67. *Connoiss.* 97. *Twelve nebulæ from ¾ of a minute to 2′ in diameter.* I. 267. II. 186, 209, 705, 836, 870. III. 152, 877. IV. 13, 14, 16, 39.

it may be expected that a time must come when it can no longer be compressed, and the only cause which we may suppose to put an end to the compression is, when the consolidated matter assumes hardness. It remains therefore to be examined, how far my observations will go to ascertain the intensity of its consolidation.

The following two assortments contain seven nebulæ, from whose appearance a considerable degree of solidity may be inferred *.

IV. 55 is "A pretty bright round nebula, almost of an even "light throughout approaching to a planetary appearance, but ill "defined, and a little fainter on the edges; it is about ¾ or 1 mi-"nute in diameter." Fig. 34.

IV. 37 is "A very bright planetary disk of about 35″ in dia-"meter, but ill defined on the edges; the center of it is rather "more luminous than the rest, and with long attention a very "bright well defined round center becomes visible." Fig. 35.

In these nebulæ we have three different indications of the compression of the nebulous matter of which they are composed: their figure, their light, and the small compass into which it is reduced. The round figure is a proof that the nebulous mass is collected into a globular form, which cannot have been effected without a certain degree of condensation.

Their planetary appearance shows that we only see a superficial lustre such as opaque bodies exhibit, and which could not happen if the nebulous matter had no other quality than that of shining, or had so little solidity as to be perfectly transparent. That there is a certain maximum of brightness occasioned by condensation, is to be inferred from the different degrees of light of round nebulæ that are in a much less advanced state of compression; for these are gradually more bright towards the center; which proves that brightness keeps up with condensation till the increase of it brings on a consolidation which will no longer permit the internal penetration of light, and thus a planetary appearance must in the end be the consequence; for planets are solid opaque bodies, shining only by superficial light, whether it be innate or reflected.

From the size of the nebulæ as we see them at present, we cannot form an idea of the original bulk of the nebulous matter they con-

* See *Four nebulæ of a planetary appearance.* IV. 55, 60, 68, 78.
Three planetary disks with a bright central point II. 268. IV. 37, 73.

tain; but let us admit, for the sake of computation, that the nebulosity of the above described nebula IV. 55, when it was in a state of diffusion, took up a space of 10′ in every cubical direction of its expansion; then, as we now see it collected into a globular compass of less than one minute, it must of course be more than nineteen hundred times denser than it was in its original state. This proportion of density is more than double that of water to air.

With regard to planetary disks, which have bright central points, we may surmise that their original diffused nebulosity was more unequally scattered, and that they passed through the different stages of extended nebulæ, gradually acquiring a nucleus, chevelure, and branches. For in nebulæ of this construction, the consolidation of a nucleus is already much advanced at the time when a considerable quantity of nebulous matter, on account of its greater central distance, remains still unformed in the branches; and if the condensation of the nucleus should keep the lead, it will come to a state of great solidity and maximum of brightness by the time that the rest of the nebulosity is drawn into a planetary appearance.

30. *Of Planetary Nebulæ.*

The objects of which I shall give an account in this article have so near a resemblance to planets, that the name of planetary nebulæ very justly expresses their appearance; for notwithstanding their planetary aspect, some small remaining haziness, by which they still are more or less surrounded, evinces their nebulous origin. In my catalogues the places of the following ten have been given*.

IV. 18 is "A beautiful bright round nebula, having a pretty "well defined planetary disk of about 10 or 12″ in diameter. It "is a little elliptical, and has a very small star following, which "gives us the idea of a small satellite accompanying its planet. It "is visible in a common finder as a small star." Fig. 36.

IV. 27 is "A beautiful very brilliant globe of light, hazy on the "edges, but the haziness going off suddenly. I suppose it to be "from 30 to 40″ in diameter, and perhaps a very little elliptical. "The light of it seems to be all over of the uniform lustre of a

* See *Planetary nebulæ* IV. 1, 11, 13. 26, 27, 34, 51, 53, 64, 70.

" star of the 9th magnitude. The haziness on the edges does not " exceed the 20th part of the diameter."

IV. 51 is " A small beautiful planetary nebula, but considerably " hazy upon the edges; it is of a uniform light, and considerably " bright, perfectly round, and about 10 or 15″ in diameter."

IV. 53 is "A pretty bright planetary nebula of nearly 1′ in dia- " meter; it is round, or a little elliptical; its light is uniform, and " pretty well defined on the borders."

IV. 64 is " A beautiful planetary nebula of a considerable de- " gree of brightness, but not very well defined, about 12 or 15″ in " diameter."

The remarks which have been made on the nebulæ of the foregoing article, will here apply with additional propriety; for the light of these planetary nebulæ must be considerably more condensed than that of the foregoing sets. The diameter of four of them does not exceed 15″, so that if we again suppose the original diffused nebulosity from which they sprang of 10′ in cubical dimensions, we shall have a condensation, which has reduced the nebulous matter to less than the one-hundred-and-twenty-two thousandth part of its former bulk.

One of them, number 34 in the 4th class, appeared even in the 20 feet telescope, with the sweeping power, like a star with a large diameter, and it was only when magnified 240 times that it resembled a small planetary nebula; nor can any of these nebulæ be distinguished from the neighbouring small stars in a good common telescope, night-glass, or finder.

When we reflect npon these circumstances, we may conceive that, perhaps in progress of time these nebulæ which are already in such a state of compression, may be still farther condensed so as actually to become stars.

It may be thought that solid bodies, such as we suppose the stars to be from the analogy of their light with that of our sun when seen at the distance of the stars, can hardly be formed from a condensation of nebulous matter; but if the immensity of it required to fill a cubical space, which will measure ten minutes when seen at the distance of a star of the 8th or 9th maguitude, is well considered, and properly compared with the very small angle our sun would subtend at the same distance, no degree of rarity of the

nebulous matter, to which we may have recourse, can be any objection to the solidity required for the construction of a body of equal magnitude with our sun*.

A circumstance which allies these very compressed nebulæ to the character of many of our well-known celestial bodies, such as some of the planets and their satellites, the sun and all periodical stars, is that very probably most, if not all, of them turn on their axis. Seven of the ten I have mentioned are not perfectly round, but a very little elliptical. Ought we not to ascribe this figure to the same cause which has flattened the polar diameter of the planets, namely, a rotatory motion?

At the end of the 26th article I have already pointed out one configuration of the nebulous matter, of which the final condensation seems to be properly disposed for bringing on a rotatory motion of the nucleus; but, if we consider this matter in a general light, it appears that every figure which is not already globular must have eccentric nebulous matter, which in its endeavour to come to the center, will either dislodge some of the nebulosity which is already deposited, or slide upon it sideways, and in both cases produce a circular motion; so that in fact we can hardly suppose a possibility of the production of a globular form without a consequent revolution of the nebulous matter, which in the end may settle in a regular rotation about some fixed axis. Many of the extended, and irregular nebulæ are considerably elliptical, and the irregular round ones shew a general approach to the oval form; now these figures are all favourable to a surmise, that a rotatory motion may often take place even before the nucleus of a nebula can have arrived to a state of consolidation. An objection, that this remarkable form of planetary nebulæ may be owing to chance, will hardly deserve to be mentioned, because the improbability of such a supposition must exclude it from all claim to refutation.

31. *Of the Distance of the Nebula in the Constellation of Orion.*

In my 3d article I concluded, from the appearance of the great nebula in Orion, that the range of the visibility of the diffused nebu-

* A cubical space, the side of which at the distance of a star of the 8th magnitude is seen under an angle of 10′, exceeds the bulk of the sun (2208000000000000000) two trillion and 208 thousand billion times.

lous matter cannot be great, because we may there see in one and the same object, both the brightest and faintest appearance of nebulosities that can be seen any where. It will therefore be a case of some interest, if we can form any conception of the place among the fixed stars to which we ought to refer the situation of this nebula; and this I believe my observation of it will enable us to determine pretty nearly.

In the year 1774, the 4th of March, I observed the nebulous star, which is the 43d of the *Connoissance des Temps*, and is not many minutes north of the great nebula; but at the same time I also took notice of two similar, but much smaller nebulous stars; one on each side of the large one, and at nearly equal distances from it. Fig. 37 is a copy of a drawing which was made at the time of observation.

In 1783, I examined the nebulous star, and found it to be faintly surrounded with a circular glory of whitish nebulosity, faintly joining to the great nebula.

About the latter end of the same year I remarked that it was not equally surrounded, but most nebulous towards the south.

In 1784, I began to entertain an opinion that the star was not connected with the nebulosity of the great nebula of Orion, but was one of those which are scattered over that part of the heavens.

In 1801, 1806, and 1810, this opinion was fully confirmed by the gradual change which happened in the great nebula, to which the nebulosity surrounding this star belongs. For the intensity of the light about the nebulous star had by this time been considerably reduced, by the attenuation or dissipation of the nebulous matter; and it seemed now to be pretty evident that the star is far behind the nebulous matter, and that consequently its light in passing through it is scattered and deflected, so as to produce the appearance of a nebulous star. A similar phenomenon may be seen whenever a planet or a star of the 1st or 2d magnitude happens to be involved in haziness; for a diffused circular light will then be seen, to which, but in a much inferior degree, that which surrounds this nebulous star bears a great resemblance.

When I reviewed this interesting object in December 1810, I directed my attention particularly to the two small nebulous stars, by the sides of the large one, and found that they were perfectly free from every nebulous appearance; which confirmed not only my

former surmise of the great attenuation of the nebulosity, but also proved that their former nebulous appearance had been entirely the effect of the passage of their feeble light through the nebulous matter spread out before them.

The 19th of January 1811, I had another critical examination of the same object in a very clear view through the 40-feet telescope; but notwithstanding the superior light of this instrument, I could not perceive any remains of nebulosity about the two small stars, which were perfectly clear, and in the same situation, where about thirty-seven years before I had seen them involved in nebulosity.

If then the light of these three stars is thus proved to have undergone a visible modification in its passage through the nebulous matter, it follows that its situation among the stars is less distant from us than the largest of the three, which I suppose to be of the 8th or 9th magnitude. The farthest distance therefore, at which we can place the faintest part of the great nebula in Orion, to which the nebulosity surrounding the star belongs, cannot well exceed the region of the stars of the 7th or 8th magnitude, but may be much nearer; perhaps it may not amount to the distance of the stars of the 3d or 2nd order; and consequently the most luminous appearance of this nebula must be supposed to be still nearer to us. From the very considerable changes I have observed in the arrangement of its nebulosity, as well as from its great extent, this inference seems to have the support of observation; for in very distant objects we cannot so easily perceive changes as in near ones, on account of the smaller angles which both the objects, and its change subtend at the eye. The following memorandum was made when I viewed it in 1774; "Its shape is not like that which Dr. Smith "has delineated in his optics, though somewhat resembling it, being "nearly as in fig. 37: from this we may infer that there are un-"doubtedly changes among the regions of the fixed stars; and "perhaps from a careful observation of this lucid spot, something "may be concluded concerning the nature of it."

In January 1783, the nebulous appearance differed much from what it was in 1780, and in September it had again undergone a change in its shape since January.

March 13, 1811. With a view to ascertain such obvious alterations in the disposition of the nebulous matter as may be depended on, I selected a telescope that had the same light and power which

thirty-seven years ago I used, when I made the above-mentioned drawing; and the relative situation of the stars remaining as before, I found that the arrangement of the nebulosity differs considerably. The northern branch N still remains nearly parallel to the direction of the stars $a\ b$; but the southern branch S is no longer extended towards the star d; its direction is now towards e, which is very faintly involved in it. The figure of the branch is also different; the nebulosity in the parallel $P\ F$ of the three stars being more advanced towards the following side than it was formerly.

I compared also the present appearance of this nebula with the delineation with Huyghens has given of it in his *Systema Saturnium*, page 8, of which fig 38 is a copy. The twelve stars which he has marked are sufficient to point out the arrangement of the nebulous matter at the time of his observation. By their situation we find that the nebula had no southern branch, nor indeed any to the north, unless we call the nebulosity in the direction of the parallel a branch; but then this branch is not parallel to a line drawn from a to the star b; moreover the star f is now involved in faint nebulosity, which also reaches nearly up to g, and quite incloses h. The star b which is now nebulous, is represented as perfectly out of all nebulosity, and can hardly be supposed to have been affected when Huyghens observed it.

The changes that are thus proved to have already happened, prepare us for those that may be expected hereafter to take place, by the gradual condensation of the nebulous matter; for had we no where an instance of any alteration in the appearance of nebulæ, they might be looked upon as permanent celestial bodies, and the successive changes, to which by the action of an attracting principle they have been conceived to be subject, might be rejected as being unsupported by observation.

The various appearances of this nebula are so instructive, that I shall apply them to the subject of the partial opacity of the nebulous matter, which has already been inferred from its planetary appearance, when extremely condensed in globular masses; but which now may be supported by more direct arguments. For when I formerly saw three fictitious nebulous stars, it will not be contended that there were three small shining nebulosities, just in the three lines in which I saw them, of which two are now gone and only one remaining. As well might we ascribe the light surrounding a star, which is seen

through a mist, to a quality of shining belonging to that particular part of the mist, which by chance happened to be situated where the star is seen. If then the former nebulosity of the two stars which have ceased to be nebulous can only be ascribed to an effect of the transit or penetration of their light through nebulous matter which deflected and scattered it, we have now a direct proof that this matter can exist in a state of opacity, and may possibly be diffused in many parts of the heavens without our being able to perceive it.

That there has been shining as well as opaque nebulous matter about the large star, appears from several observations I have made upon the light which surrounded it. In 1783 the nebulosity about it was so considerable in brightness, and so much on one side of it, that the star did not appear to have any connection with it. The reason of which is plainly, that the shining quality of the nebulous matter then overpowered the feeble scattering of the light of the star in the nebulosity.

32. *Of Stellar Nebulæ.*

It has been remarked that diffused nebulosities may exist unknown to us, among the more distant regions of the fixed stars; and though we may not be able to see a nebulous diffusion that is farther from us than the moderate distance at which we now have reason to suppose the faintest visible nebulosity of the nebula in Orion to be placed; yet if some former diffusion of the nebulous matter should be already reduced into separate and much condensed nebulæ, they might then come within the reach of telescopes that have a great power of collecting light: this being admitted, there is a probability that some of the various diffusions of the nebulous matter, from which our present nebulæ derive their origin, may have been much farther from us than others. For, in every description of figure, size and condensation, of which I have given instances, we find not only very bright and very large, but also faint and small, as well as extremely faint and extremely small nebulæ; and the same gradations will now be found to run through that class which I have called stellar nebulæ. This classification was introduced in my sweeps when the objects to be recorded came in so quick a succession that I found it expedient to express as much as I could in as few words as possible, and by calling a nebula stellar, I intended to denote that the object to which I gave this name was, in the first

place as small, or almost as small, as a star; and in the next, that notwithstanding its smallness, and starlike appearance, it bore evident marks of not being one of those objects which we call stars, and of which I saw many at the same time in the telescope.

The following three collections contain one hundred and seventeen stellar nebulæ, which have been assorted by their brightness, that their comparative condensation might be estimated according to the different distances at which we may suppose other nebulæ of the same degree of light to be placed *.

I. 71 is "A considerably bright, very small, almost stellar nebula; "the brightness diminishing insensibly and breaking off pretty "abruptly. The whole together is not more than about 7 or 8″ in "diameter." A second observation, made in a remarkable clear morning, says, that "the greatest brightness is towards the following "side, and that the very faint nebulosity extends to near a minute."

This is probably a condensation of a former nucleus with surrounding chevelure.

I. 268 is "A very bright, very small, round stellar nebula." Fig. 39.

This may be a former planetary nebula in a higher state of condensation.

II. 110 is "A very bright small stellar nebula or star with a bur "all a-round." Fig. 40.

This star with a bur is propably one that was formerly a planetary nebula with a pretty strong haziness on the borders.

II. 603 is "A pretty bright stellar nebula, or a pretty considerable star with a very faint chevelure." Fig. 41.

This may have been a planetary nebula with a faint haziness about the margin.

IV. 46 is "A very small pretty bright, or considerably bright "stellar nebula, like a star with burs."

It may have been a pretty well defined planetary nebula.

If it should be deemed singular that we have not a greater number of bright stellar nebulæ, I must remark that, if the stellar is a succession of the planetary state, the number of bright stellar is sufficiently proportionable to that of the planetary nebulæ; and as the faint nebulæ are far more numerous than the bright ones, so it will be seen by the references in the two next assortments, that in propor-

* See *First assortment containing six of the brightest stellar nebulæ.* I. 71, 268. II, 110, 603. IV. 32, 46.

tion as brightness decreases, we have a much more copious collection of stellar nebulæ *.

II. 663 is "A pretty bright very small stellar nebula."

This nebula and the rest of them, which are all of the same description, must be looked upon as condensations of distant nebulæ that had nuclei, or were nearly about the planetary condition †.

In this collection of nebulæ we have many of a different description. In some, the mark whereby they were distinguished from stars was their figure, the object not being so small but that its figure might still be perceived. Of others, some difference in the brightness between the center and outside was visible; and many of them were only called stellar, because by some deficiency or other in the appearance it was evident they were not perfect stars. Instances of every sort will be seen in the following descriptions.

II. 424 is "A very faint stellar nebula, or a little larger."

II. 805 is "An extremely faint very small round stellar nebula."

II. 425 is "A faint very small stellar nebula, of an irregular "figure."

III. 145 is "A very faint stellar nebula; a little extended."

III. 691 is "A considerably faint stellar nebula, suddenly much "brighter in the middle."

33. *Of Stellar Nebulæ nearly approaching to the Appearance of Stars.*

The starlike appearance of the following six nebulæ is so considerable that the best description, which at the time of observation I could give of them, was to compare them to stars with certain deficiencies ‡.

---

* See *Second assortment containing eleven stellar nebulæ of the next degree of brightness.* II. 159, 178, 179, 204, 232, 663, 676, 689, 708, 820, 867.

† See *Third assortment containing one hundred stellar nebulæ of several degrees of faintness.* II. 127, 194, 244, 340, 341, 425, 443, 448, 449, 454, 550, 551, 576, 618, 620, 692, 693, 718, 721, 722, 735, 740, 781, 815, 848, III. 81, 109, 114, 119, 125, 136, 145, 151, 161, 167, 168, 169, 170, 171, 172, 173, 175, 188, 215, 231, 232, 234, 240, 260, 276, 277, 278, 289, 294, 320, 322, 341, 400, 401, 418, 422, 423, 424, 438, 439, 469, 476, 530, 536, 561, 562, 563, 564, 565, 571, 576, 590, 606, 627, 672, 691, 706, 737, 741, 764, 768, 770, 772, 777, 786, 793, 805, 815, 821, 828, 843, 852, 855, 856, 916.

‡ See *Three stars with burs.* II. 655. IV. 47, 49.

IV. 49 is "A pretty bright stellar nebula, like a star with a "small bur all around."

The other two are of the same nature*.

IV. 15 is "A stellar nebula, or rather like a faint star with a "small chevelure and two burs."

The other two are nearly of the same description.

34. *Of Doubtful Nebulæ.*

It may have been remarked, that many stellar nebulæ of my catalogues have the memorandum added to their descriptions that they were confirmed with a higher magnifying power, and that this was sometimes attended with difficulty, and sometimes could not be successively done.

A collection of thirty-four nebulæ that come under this description is as follows†:

II. 470 is "A small stellar nebula." By a second observation a doubt entertained in the first was removed with 240, which shewed it "pretty bright, but hardly to be distinguished from a star."

III. 29 is "A very faint extremely small stellar nebula, or rather "nebulous star." The sweeping power left me rather doubtful; "240 verified it.

It must be noticed, that in these nebulæ the doubt which was entertained did not relate to the existence of the objects, but merely to their nature; and when the suspected nebula was so faint that even its existence was doubtful, a higher power was applied only with a view to ascertain whether the object existed as nebula or as star; for had the suspicion of its existence not been accompanied with the expectation of its being a nebula, it could never have been attempted to be verified ‡.

III. 270 is "A very faint extremely small stellar nebula; 240 "verified it with difficulty and considerable attention, the night "being uncommonly clear."

---

* See *Three stars with a faint chevelure.* IV. 15, 21, 31.

† See *First assortment containing twenty-five verified stellar nebulæ.* II. 470, 502, 661. III. 29, 80, 84, 124, 135, 174, 184, 187, 202, 207, 214, 226, 254, 266, 268, 269, 513, 549, 604, 742, 748, 964.

‡ See *Second assortment, containing five stellar nebulæ verified with difficulty.* III. 115, 212, 219, 262, 270.

When difficulty is mentioned, it is always to be understood that a considerable time as well as attention was required in the examination before a decisive opinion could be formed *.

III. 7 is "A nebulous star, but doubtful of the nebulosity. "With 240 the same doubtful appearance continues." Fig. 42.

With this object the doubt which remained could only relate to the nature of it; for being at first sight taken to be a nebulous star, its existence could not be a subject for examination; but the unresolved doubt, whether an object is a nebula or a star, must certainly be allowed to be as great a proof of identity as we can possibly expect to see.

35. *Concluding Remarks.*

The total dissimilitude between the appearance of a diffusion of the nebulous matter and of a star, is so striking, that an idea of the conversion of the one into the other can hardly occur to any one who has not before him the result of the critical examination of the nebulous system which has been displayed in this paper. The end I have had in view, by arranging my observations in the order in which they have been placed, has been to show, that the above-mentioned extremes may be connected by such nearly allied intermediate steps, as will make it highly probable that every succeeding state of the nebulous matter is the result of the action of gravitation upon it while in a foregoing one, and by such steps the successive condensation of it has been brought up to the planetary condition. From this the transit to the stellar form, it has been shown, requires but a very small additional compression of the nebulous matter, and several instances have been given which connect the planetary to the stellar appearance.

The faint stellar nebulæ have also been well connected with all sorts of faint nebulæ of a larger size; and in a number of the smaller sort, their approach to the starry appearance is so advanced, that in my observations of many of them it became doubtful whether they were not stars already.

It must have been noticed, that I have confined myself in every one of the preceding articles to a few remarks upon the appearance

* See *Third assortment, containing four objects that could not be verified.* III. 7, 176, 263, 293.

of the nebulous matter in the state in which my observations represented it; they seemed to be the natural result of the observations under consideration, and were not given with a view to establish a systematic opinion, such as will admit of complete demonstration. The observations themselves are arranged so conveniently that any astronomer, chemist, or philosopher, after having considered my critical remarks, may form what judgment appears most probable to him. At all events, the subject is of such a nature as cannot fail to attract the notice of every inquisitive mind to a contemplation of the stupendous construction of the heavens; and what I have said may at least serve to throw some new light upon the organization of the celestial bodies.

Synopsis of the Contents of this Paper.

POSTSCRIPT.

It will be seen that in this paper I have only considered the nebulous part of the construction of the heavens, and have taken a star for the limit of my researches. The rich collection of clusters of stars contained in the 6th, 7th, and 8th classes of my Catalogues, and many of the *Connoissance des Temps*, have as yet been left unnoticed. Several other objects, in which stars and nebulosity are mixed, such as nebulous stars, nebulæ containing stars, or suspected clusters of stars which yet may be nebulæ, have not been introduced, as they appeared to belong to the sidereal part of the construction of the heavens, into a critical examination of which it was not my intention to enter in this paper.

WILLIAM HERSCHEL.

Slough, near Windsor,
May 26, 1811.

[*Herschel*, Phil. Trans. 1811.]

CHAP. VIII.

RECAPITULATION OF DR. HERSCHEL'S VERY INGENIOUS AND IMPORTANT OBSERVATIONS IN THE PRECEDING CHAPTER.

Dr. Herschel supposes that the luminous fluid which so often appears in different parts of the heavens, and throws streaks athwart them, is not light immediately issuing from stars too remote to be traced by the telescope, but existing independently of stars or planets, though perhaps originally thrown forth from them.

It is not matter of light alone, for it is sometimes capable of opacity, though usually luminous, and a source of light. When this subtle material exists in irregular loose masses he calls it a *nebulosity*, or luminous cloud. Its residence he supposes to be within the range of the remotest stars, though beyond those of the second and third magnitudes; yet similar diffusions, he conceives, may also exist at distances where they cannot be seen.

Agreeably to the laws of gravitation or the centripetal force, he supposes the different particles to have a tendency of approaching to each other, and that some circumstances, unknown to us, may occasion a preponderating influence, usually in the centre of a diffused mass, but sometimes in other quarters. Hence, a luminous nucleus will be produced by the concentration that must necessarily follow, which will progressively attract and determine the circumjacent luminous matter to itself, and diminish the extent of the general range; and in this case what was a *nebulosity* will become a *nebula*.

The nuclei may sometimes be double, or triple, or still more complicated in the same nebulosity, and whenever this occurs, the nebulosity will be broken into different nebulæ, or smaller luminous clouds; and if some of them be much minuter than others, they may ultimately attend upon them as satellites upon a planet. If the nebulæ have a hazy or superficial lustre, he calls them *planetary;* if they be uniformly luminous, he denominates them *stellar*.

Dr. Herschel conceives that stars, planets, and comets, may all occasionally originate from such a source; that a rotatory motion must ensue from the preponderancy of action of a greater mass of particles on one side of the nucleus than on other sides: and that, as many of these particles are probably elastic, an apparent haze or chevelure, coma or hair, must often appear to surround the nucleus. When the whole of the luminous circumferent matter is consolidated by gravitation into the nucleus, the planetary *nebula* becomes then a real *star;* some of which stars, before they become perfectly consolidated, have visibly faint chevelures, or else burs, or prickles. The nebulous matter contained in a cubical space seen under an angle of ten degrees, will admit of a condensation of two trillion and two hundred and eight thousand billion times, before it can be so consolidated as to constitute a globe of the diameter of our sun.

The ground-work of these opinions, or the principles from which these results are drawn, will be found at length in the preceding chapter, and they are too curious and of too much consequence for us to diminish their force by an abridgment. Yet the younger and the less inquisitive among our readers, will feel obliged to us for presenting them, in the chapter before us, with a miniature view of the general information they contain.

Editor.

CHAP. IX.

ACCOUNT OF DR. HERSCHEL'S PAPER ON THE CHANGES THAT HAVE HAPPENED DURING THE LAST TWENTY-FIVE YEARS, IN THE RELATIVE SITUATION OF DOUBLE STARS; WITH AN INVESTIGATION OF THE CAUSE TO WHICH THEY ARE OWING.

DR. Herschel devotes this paper principally to the consideration of the second class of the systems into which he has divided the sidereal world. After cursorily remarking, with respect to the solar system, as a specimen of the first class, which, among the insulated stars, comprehends the Sun, that the affections of the newly discovered celestial bodies extend our knowledge of the construction of this insulated system, which is best known to us; he proceeds to support, by the evidence of observation, the opinion which he has before advanced, of the existence of binary sidereal combinations, revolving round the common centre of gravity; Dr. Herschel first considers the apparent effect of the motion of either of the three bodies concerned, the two stars, and the Sun with its attendant planets; and then states the arguments respecting the motions of a few only out of the fifty double stars, of which he has ascertained the revolutions. The first example is Castor, or alpha Geminorum: here Dr. Herschel stops to show how accurately the apparent diameter of a star, viewed with a constant magnifying power, may be assumed as a measure of small angular distances; he found that ten different mirrors, of seven feet focal length, exhibited no perceptible difference in this respect. In the case of Castor no change of the distance of the stars has been observed, but their angular situation appears to have varied somewhat more than 45° since it was observed by Dr. Bradley, in 1759; and they have been found by Dr. Herschel, in intermediate positions at intermediate times. Dr. Herschel allows that it is barely possible that a separate proper motion, in each of the stars and in the Sun, may have caused such a change in the relative situation, but that the probability is very decidedly in favour of the existence

of a revolution. Its period must be a little more than 342 years, and its plane nearly perpendicular to the direction of the Sun. The revolution of gamma Leonis is supposed to be in a plane considerably inclined to the line in which we view it, and to be performed in about 1200 years. Both these revolutions are retrograde; that of epsilon Bootis is direct, and is supposed to occupy 1681 years, the orbit being in an oblique position with respect to the Sun. In zeta Herculis, Dr. Herschel observed, in 1802, the appearance of an occultation of the small star by the larger one: in 1782 he had seen them separate; the plane of the revolution must therefore pass nearly through the Sun; and this is all that can at present be determined respecting it. The stars of delta Serpentis appear to perform a retrograde revolution in about 875 years: their apparent distance is invariable, as well as that of the two stars which constitute gamma Virginis, the last double star which Dr. Herschel mentions in this paper, and to which he attributes a periodical revolution of about 708 years.

[*Young's Nat. Philosoph.* Vol. II.—*Journals of the Royal Institution*, Vol. II.]

CHAP. X.

DR. HERSCHEL'S OBSERVATIONS OF THE COMET OF THE YEAR 1811, WITH REMARKS ON THE CONSTRUCTION OF ITS DIFFRENET PARTS.

THE Comet which has lately visited the solar system has moved in an orbit very favourably situated for astronomical observations. I have availed myself of this circumstance, and have examined all the parts of it with a scrutinizing attention, by telescopes of every degree of requisite light, distinctness, and power.

The observations I have made have been so numerous, and so often repeated, that I shall only give a selection of such as were made under the most favourable circumstances, and which will serve to ascertain the most interesting particulars relating to the construction of the comet.

THE COMET OF 1811,

As seen at Day break the 15.th Oct.r from Otterbourne Hill, near Winchester.

As my attention in these observations were every night directed to as many particulars as could be investigated, it will be most convenient to assort together those which belong to the same object; and in the following arrangement I shall begin with the principal part, which is

The planetary Body in the Head of the Comet.

By directing a telescope to that part of the head where with the naked eye I saw a luminous appearance not unlike a star, I found that this spot, which perhaps some astronomers may call a nucleus, was only the head of the comet; but that within its densest light there was an extremely small bright point, entirely distinct from the surrounding glare. I examined this point with my 20 feet, large 10 feet, common 10 feet, and also with a 7 feet telescope; and with every one of these instruments I ascertained the reality of its existence.

At the very first sight of it, I judged it to be much smaller than the little planetary disk in the head of the comet of the year 1807; but as we are well assured that if any solidity resembling that of the planets be contained in the comet, it must be looked for in this bright point; I have called it the planetary body; in order to distinguish it from what to the naked eye or in small telescopes appeared to be a nucleus, but which in fact was this little body with its surrounding light or head seen together as one object.

With a new 10 feet mirror of extraordinary distinctness, I examined the bright point every fine evening, and found that although its contour was certainly not otherwise than round, I could but very seldom perceive it definedly to be so.

As hitherto I had only used moderate magnifiers from 100 to 160, because they gave a considerable brightness to the point, it occurred to me that higher powers might be required to increase its apparent magnitude; accordingly the 19th of October, having prepared magnifiers of 169, 240, 300, 400, and 600, I viewed the bright point successively with these powers.

With 169 it appeared to be about the size of a globule which in the morning I had seen in the same telescope and with the same magnifier, and which by geometrical calculation subtended an angle of 1″,39.

I suspected that this apparent size of the bright point was only such as will spuriously arise from every small star-like appearance;

and this was fully confirmed when I examined it with 240; for by this its magnitude was not increased; which not only proved that my power was not sufficient to reach the real diameter of the object, but that the light of this point was, like that of small stars, sufficiently intense to bear being much magnified.

I viewed it next with 300, and here again I could perceive no increase of size.

When I examined the point with 400, it appeared to me somewhat larger than with 300; I saw it indeed rather better than with a lower power, and had reason to believe that its real diameter was now within reach of my magnifiers. Curiosity induced me to view it in the 7 feet telescope with a power of 460; and notwithstanding the inferior quantity of light of this instrument, the magnitude was fully sufficient to show that the increase of size in this telescope agreed with that in the 10 feet.

Returning again to the latter I examined the bright point with 600, and saw it now so much better than with 400, that I could keep it steadily in sight while it passed the field of view of the eye-glass.

With this power I compared its appearance to the size of several globules, that have been examined with the same telescope and magnifier, and by estimation I judged it to be visibly smaller than one of 1″,06 in diameter, and rather larger than another of 0″,68.

It should be noticed that I viewed the globules, which were of sealing-wax, without sunshine, in the morning after the observation as well as the morning before; referring in one case the bright point to the globules, and in the other the globules to the bright point*.

The apparent and real Magnitude of the planetary Body.

The size of the bright point being much more like the smallest of the two globules, shall add one quarter of their difference to 0″,68, and assume the sum, which is 0″,775 as the apparent diameter of the planetary disk.

Then by a calculation from some corrected elements of the comet's orbit, which, though not very accurate, are however sufficiently so for my purpose, I find that the distance of the comet from the

* A similar method was used with the comet of 1807. See Phil. Trans. for 1808, page 145.

earth, at the time of observation, was nearly 114 millions of miles; from which it follows that the bright point, or what we may admit to be the solid or planetary body of the comet, is about 428 miles in diameter.

The Eccentricity and Colour of the planetary Body.

The situation of the bright point was not in the middle of the head, but was more or less eccentric at different times.

The 16th of October that part of the head which was towards the sun, was a little brighter and broader than that towards the tail, so that the planetary disk or point was a little eccentric.

The 17th I found its situation to be a little beyond the centre, reckoning the distance in the direction of a line drawn from the sun through the centre of the head.

The 4th of November it was more eccentric than I had ever seen it before.

Nov. 10, I found no alteration in the eccentricity since the last observation.

The colour of the planetary disk was of a pale ruddy tint, like that of such equally small stars as are inclined to red.

The Illumination of the planetary Body.

The smallness of the disk, even when most magnified, rendered any determination of its shape precarious; however had it been otherwise than round, it might probably have been perceived; the phasis of its illumination at the time of observation being to a full disk as 1,6 to 2.

From this as well as from the high magnifying power, which a point so faint could not have borne with advantage, had it shone by reflected light, we may infer that it was visible by rays emitted from its own body *.

* On the subject of the nature of the light by which we see this comet, I may refe to what has been said in my paper of observations on that of the year 1807. Those who wish also to consult the opinion of an eminent philosopher, whose valuable works on meteorological subjects are well known, will find it expressed at large in a letter from Mr. De Luc, addressed to Mr. Bode, so far back as the year 1799, and reprinted in Mr. Nicholson's Journal, published the 1st of March 1809.

The Head of the Comet.

It has already been noticed that the brightest part of the comet seen by the naked eye, appeared to contain a small star-like nucleus. When this was viewed in a night-glass, or finder, magnifying only 6 or 8 times, it might still have been mistaken for one; but when I applied a higher power, such as from 60 to 120, it retained no longer this deceptive appearance; which evidently arises from an accumulation of light, condensed into the small compass of a few minutes; and which of course will vanish when diluted by magnifying.

Sept. 2, I saw the comet at Glasgow, in a 14 feet Newtonian reflector; but being very low, the moon up, and the atmosphere hazy, it appeared only like a very brilliant nebula, gradually brighter in a large place about the middle.

The 9th and 10th of September at Alnwick, I viewed it with a fine achromatic telescope, and found that, when magnified about 65 times, the planetary disk-like appearance seen with the naked eye, was transformed into a bright cometic nebula, in which, with this power, no nucleus could be perceived.

The 18th of September the star-like object in my large 10 feet reflector, when magnified 110 times, had the appearance of a fine globular luminous nebula; it seemed to be about 5 or 6 minutes in diameter, of which one or two minutes about the centre were nearly of equal brightness. The small 10 feet showed it in the same manner.

In all my instruments this bright appearance was equally transformed into a brilliant head of the comet, with this difference, that when high powers were applied, the central illumination which, moderately magnified, was pretty uniform, became diluted into a gradual decrease from the middle towards the outside; losing itself by imperceptible degrees, especially towards the sides and following parts, into a darkish space, which, from observations that will be given hereafter, I take to be a cometic atmosphere.

The Colour and Eccentricity of the Light of the Head.

The colour of the head being very remarkable, I examined it with all my different telescopes; and in every one of them, its light appeared to be greenish, or bluish green. Its appearance was certainly very peculiar,

The disposition of the light of the head was likewise accompanied with some remarkable circumstances; for notwithstanding a general accumulation about the middle, there seemed to be a greater share of it towards the sun, than a portion in that situation of the circumference was entitled to, had it been uniformly arranged; and if we look upon the head as a coma to the planetary point, the eccentricity of its light will be still more evident; for this point was constantly more or less farther from the sun than the middle of the greatest brightness of the light surrounding it. The eccentricity of the head was indeed so considerable, that considering the difficulty of seeing the point, it might easily have escaped the notice of one who looked for it in the centre of the head.

The apparent and real Magnitudes of the Head.

With an intention to ascertain the dimensions of the various parts of the comet, I viewed the head in the 7, 10, and 20 feet telescopes, and estimated its size by the proportion it bore to the known fields of the eye-glasses that were used. I shall only mention two estimations: September 29, the 10 feet gave its apparent diameter 3′ 0″. With the 20 feet, Oct. 6, it was 3′ 45″.

From a calculation of the 20 feet measure, which I prefer, it appears that the real diameter of the head at this time was about 127 thousand miles.

A transparent and elastic Atmosphere about the Head.

In every instrument through which I have examined the comet, I perceived a comparatively very faint or rather darkish interval surrounding the head, wherein the gradually diminishing light of the central brightness was lost. This can only be accounted for by admitting a transparent elastic atmosphere to envelop the head of the comet.

Its transparency I had an opportunity of ascertaining the 18th of September, when I saw three very small stars of different magnitudes within the compass of it; and its elasticity may be inferred from the circular form under which it was always seen. For being surrounded by a certain bright equi-distant envelop, we can only account for the equality of the distance by admitting the interval between the envelope and the head of the comet to be filled with an elastic atmospherical fluid.

The Extent of the cometic Atmosphere.

When I examined the comet in the 20 feet telescope the 6th of October, the circular darkish space, which surrounded the brightness, just filled the field of the eye-glass; which gives its apparent diameter 15 minutes. This atmosphere was therefore more than 507 thousand miles in diameter; but its real extent of which, as will be seen, we can have no observation, must far exceed the above calculated dimensions.

The bright Envelope of the cometic Atmosphere.

When I observed the comet at Alnwick in an achromatic refractor with a magnifying power of 65, I perceived that the head of it was partly surrounded by a train of light, which was kept at some considerable distance by an interval of comparative darkness; and from its concentric figure I call this light an envelope.

The Figure, Colour, and Magnitude of the Envelope.

On viewing this envelope in telescopes that magnify no more than about 16 times, or in finders and night-glasses with still lower powers, I found that its shape, as far as it extended, was apparently circular; but that in its course it did not reach quite half way round the head of the comet. A little before it came so far it divided itself into two streams, one passing by each side of the head.

The colour of the envelop in my 7, 10, and 20 feet telescopes had a strong yellowish cast, and formed a striking contrast with the greenish tint of the head.

The distance of the outside of the envelope from the centre of the head, in the direction of a line drawn from it to the sun was about 9′ 30″; and supposing it to have extended sideways, without increase of distance as far as a semi-circle, this would give its diameter about 19 minutes. By computation therefore its real diameter must have exceeded 643 thousand miles.

The Tail of the Comet.

The most brilliant phenomenon that accompanies a comet is the stream of light which we call the tail. Its length is well known to be variable; but the measures or estimations of its extent cannot be expected to be very consistent from several causes foreign to its actual change.

The 2d of September, the moon being up, the comet very low, and the atmosphere hazy, I could perceive no tail.

The 9th, it had a very conspicuous one, about 9 or 10 degrees in length.

On the 18th, the length was 11 or 12 degrees.

The 6th of October it was 25 degrees.

The 12th I estimated it to be only 17 degrees long.

The 14th it appeared to extend to 17½ degrees.

The 15th, by very careful attention, and in a very clear atmosphere, I found the tail to cover a space of 23½ degrees in length.

The greatest real Length of the Tail.

Of the two observations which were made of the greatest length of the tail of the comet, I prefer that of the 15th of October, on account of the clearness of the night.

The apparent length being 23½ degrees, its real extent, taking into the calculation the oblique position in which we saw it, must have been upwards of 100 millions of miles.

The Breadth of the Tail.

The variations in the breadth of the tail will hardly admit of any description; the scattered light of the sides being generally lost by its faintness in such a manner as to render its termination very doubtful.

The 12th of October its breadth in the broadest part was 6¾ degrees, and about 5 or 6 degrees from the head it began to be a little contracted.

The 15th, it was nearly of the same breadth about the middle of its length.

By calculating from the observation of the 12th, we find that the real breadth of the tail on that day was nearly 15 millions of miles.

The Curvature of the Tail.

The shape of the tail with respect to its curvature is generally considered only as it relates to the direction of the motion of the comet; it is nevertheless subject to variations arising from causes that will be noticed in the next article, but which are not taken into the account of the following observations.

The 9th and 10th of September the curvature of the tail was very considerable.

The 18th, I remarked, that towards the end of the tail its curvature had the appearance as if, with respect to the motion of the comet, that part of the tail were left a little behind the head.

The 17th of October the tail appeared to be more curved than it had been at any time before.

Dec. 2, the flexure of the curvature of the tail, contrary to its former direction, was convex on the following side.

The general Appearance of the Tail.

On account of the great length and breadth of the tail of the comet, a night-glass with a large field of view is the most proper instrument for examining its appearance. Mine takes in 4° 41′.

By viewing the comet with this glass I found the tail to be inclosed at the sides by the two streams which I have described as the continuation of the bright arch, or envelope surrounding the head.

Sept. 18, I observed that the two streams or branches arising from the sides of the head, scattered a considerable portion of their light as they proceeded towards the end of the tail, and were at last so much diluted that the whole of the farthest part of the tail contained only a scattered light.

Oct. 12. I remarked that the two streams remained sufficiently condensed in their diverging course to be distinguished for a length of about six degrees, after which their scattered light began to be pretty equally spread over the tail.

Oct. 15. The preceding branch of the tail was 7° 1′ in length. The following was only 4° 41′; which caused the appearance of an irregular curvature.

Nov. 3. The two branches were nearly of an equal length.

Nov. 5.. The length of the preceding stream was 5° 16′; that of the following about 4° 41′.

Nov. 9. The two branches might still be seen to extend full 4 degrees, but their light was much scattered.

Nov. 10. The preceding branch was 5° 16′ long; the following one only 3° 31′; the preceding one was also fuller and broader.

In the course of these observations I attended also to the appearance of the nebulosity of the tail.

Sept 18. The appearance of the nebulosity, examined with a 10 feet reflector, perfectly resembled the milky nebulosity of the nebula in the constellation of Orion, in places where the brightness of the one was equal to that of the other.

Nov. 9. The tail of the comet being very near the milky-way, the appearance of the one compared to that of the other, in places where no stars can be seen in the milky-way, was perfectly alike.

The Return of the Comet to the Nebulous Appearance.

From the observations of the decreasing length of the tail, the diminution of brightness and increased scattering of the streams, and from the gradually fainter appearance of the transparent atmosphere, brought on by the contraction and more scattered condition of the envelope, I had reason to suppose that all the still visible cometic phænomena of planetary body, head, atmosphere envelope, and tail, would soon be reduced to the semblance of a common globular nebula; not from the increase of the distance of the comet, which could only occasion an alteration in the apparent magnitude of the several parts, but by the actual physical changes which I observed in the construction of the comet.

The gradual vanishing of the Planetary Body.

Nov. 4. 10-feet reflector. I saw the planetary disk with 289. It was rather more eccentric than usual.

Nov. 9. I saw it imperfectly with 169. It was more visible with 240; but the nebulosity of the envelope overpowered its light already so much that no good observations could be made of it.

Nov. 10. Large 10-feet. I had a glimpse of the disk and its eccentricity.

Nov. 13. I tried all magnifiers, but could no longer perceive the planetary body.

The Disappearance of the Transparent Part of the Atmosphere under the Cover of the scattered Light of the contracted Envelope.

Nov. 4. In the night-glass, that part of the atmosphere which used to separate the envelope from the head, could no longer be distinguished.

In the ten-feet reflector, with a large double eye-glass, I found

the envelop drawn nearer to the head, its central distance at the vertex being less than 7′ 10″; and the atmosphere was almost involved in the scattered haziness of the streams.

Nov. 5. The envelope was still disengaged from the head, but much scattered light had nearly effaced the cometic atmosphere on the side towards the sun.

Nov. 9. The atmosphere was nearly covered by the approximation, or scattering light, of the envelope. Its vertical distance was 5′ 45″.

Nov. 10. The envelope could only be distinguished from the head by a small remaining darkish space, in which the atmosphere might still be seen. The vertical distance of the envelope was 4′ 46″.

Nov. 13. The atmosphere was almost effaced by scattered light towards the sun, but on the opposite side it was darker, or rather more transparent.

Nov. 14, 15, and 16. The atmosphere was gradually more covered in.

Nov. 19. I found in the 10 feet telescope, the envelope so broad and scattered as to leave no room for seeing the atmosphere; and the comet seemed to be fast returning to the mere appearance of a nebula.

Nov. 24. The envelope was turned into haziness; and on the side towards the sun, the comet had already the appearance of a globular nebula, with a faint hazy border.

Dec. 2. The haziness of the border was of a different colour from the light of the head, which preserved its former greenish appearance.

Dec. 9. The envelope, which had been turned into a hazy border of light, in which state I saw it again the 5th, was very unexpectedly renewed. It was however very narrow and much fainter than it used to be. By four measures I found its distance from the centre of the head to be about 4¼ minutes.

Dec. 14. The narrow faint envelope of the 9th existed no longer.

If the scattered light near the head should not be raised again, all observations of the atmosphere must be at an end; for the space beyond this light being equally clear, we have nothing left to point out any extent that might be supposed to contain a transparent elastic fluid, notwithstanding it should remain in its former situation.

Uncommon Appearances in the Dissolution of the Envelope.

Nov. 4. 10-feet. The envelope was double towards the sun, and divided itself at each side into three streams; the outside ones being very faint, and of no great length.

Nov. 5. On the preceding side the envelope was very faintly accompanied by an outer one, but not on the following side.

Nov. 13. On the following side the envelope diverged into three streams, the two outside ones being very faint and narrow; but on the preceding side there was but one additional streamlet, which was at the distance of the outermost one of the opposite side.

Nov. 14. On the preceding side there was a very faint outward stream, and on the following side there was a still fainter and shorter stream, also on the outside.

Dec. 14. There was only one short and faint outside stream at the preceding side.

Uncommon Variations in the Length of the Streams.

It has already been mentioned, that the streams or branches were subject to a considerable difference in their respective lengths; in order if possible to discover the cause of the observed changes, I continued my observations of them.

Oct. 15, and Nov. 5 and 10, the preceding branch was the longest.

The 3d and 9th of Nov. the branches were of equal length.

The 13th, the following was 4° 6′ long, the preceding only 3° 31′

The 14th. They were both of the equal length of about 3° 31′.

The 15th. The preceding branch was 3° 13′ long, the following 4° 6′.

The 16th. The preceding was 3° 13′ long, the following 3° 48′.

The 19th. The branches were equal, and about 4° 23′ long.

Dec. 2. The branches were nearly equal, and about 3° 12′ long; they joined more to the sides than the vertex, and had lost their former vivid appearance; their colour being changed into that of scattered light.

The 9th and 14th. The branches were already so much scattered that observations of them could no longer be made with any accuracy.

With regard to its transparent cometic atmosphere, we have not only the constant observations of its roundness, during the above-mentioned long period of the comet's motion, to prove it to be spherical; but in addition to this, I have already shown that it is of an elastic nature, for which reason alone, had we no other, its globular figure could not be doubted.

A most singular circumstance, which however must certainly be admitted, is, that the constant appearance of the bright envelop, with its two opposite diverging branches, can arise from no other figure than that of an inverted hollow cone, terminating at its vertex in an equally hollow cap, of nearly a hemispherical construction; nor can the sides or caps of this hollow cone be of any considerable thickness.

The proof of this assigned construction is, that the bright envelop has constantly been seen in my observation as being every where nearly equidistant from the transparent atmosphere; now if that part of it which in a semi-circular form surrounds the comet, on the side exposed to the sun, were not hemispherical, but had the shape of a certain portion of a ring, like that which we see about the planet Saturn, it must have been gradually transformed from the appearance of a semi-circle into that of a straight line, during the time that we have seen it in all the various aspects presented to us by a geocentric motion of the comet, amounting to 90 degrees.

That this hemispherical cap is comparatively thin, is proved from the darkness and transparency of that part of the atmosphere which it covers; for had the curtain of light, which was drawn over it, been of any great thickness, the scattered rays of its lustre would have taken away the appearance of this darkness; nor would the atmosphere have remained sufficiently transparent for us to see extremely small stars through it.

It remains now only to account for the semi-circular appearance of the bright envelop; but this, it will be seen, is the immediate consequence of the great depth of light near the circumference, contrasted with its comparative thinness towards the centre. The 6th of October, for instance, the radius of the envelop was 9′ 30″ on the outside, and 7′ 30″ on the inside; and as the greatest brightness was rather nearer to the outside, we may suppose its radius to have been about 8¾′. Then if we compute the depth of the lumi-

nous matter at this distance from the centre, we find that it could not be less than 248 thousand miles; whereas in the place where the atmosphere was darkest, its thickness would be only about 50 thousand; so that a superior intensity of light in the ratio of about 5 to 1, could not fail to produce the remarkable appearance of a bright semi-circle, enveloping the head of the comet at the distance at which it was observed *.

I have entered so fully into the formation of the envelope, as the argument, by which its construction has been analysed, will completely explain the appearance of the streams of light inclosing the tail of the comet, and indeed its whole construction.

The luminous matter as it arises from the envelope, of which it is a continuation, is thrown a little outwards, and assumes the appearance of two diverging bright streams or branches; but if the source from which they rise be the circular rim of an hemispherical hollow shell, the luminous matter in its diverging progress upwards can only form a hollow cone; and the appearance of the two bright streams inclosing the tail, after what has been said of the envelope, will want no farther explanation.

Add to this that, having actually seen these brilliant streams remain at the borders of the tail in the same diverging situation during a motion of the comet through more than 130 degrees, the hollow conical form of the comet's tail is in fact established by observation.

The feebler light of the tail between its branches is sufficiently accounted for by the thinness of the luminous matter of the hollow cone through which we look towards the middle of the tail compared with its great depth about the sides; and indeed the comparative darkness of the inside of the cone and transparency of the atmosphere seen through the envelope, bear witness to their hollow

* From the measures of the envelope, whose diameter the 6th of October was 643032 miles, we have the radius *a b*, 321516. Then if *c d* be 25000, we find the angle *b a c*, of which *a c* is cosine 22° 44′ 37″; and the sine *b c*, which is the depth, will be to the versed sine *c d*, which is the thickness, as 4,972 to 1. And if *a d* is 9′ 30″, the greatest brightness which is at *c* will give the distance *a c* equal to 8′ 45″,7. This calculation being made for that part which is convex towards us, the addition of the concave opposite side will double the dimensions of the depth and thickness.

construction; for, were these parts solid, both the cone and the hemispherical termination of it must have been much brighter in the middle than towards the circumference, which is contrary to observation.

CHAP. XI.

CONSTRUCTION OF THE COMET OF 1811, AS DETERMINED BY PROFESSOR BURCKHARDT, OF GOTTINGEN, MEMBER OF THE NATIONAL INSTITUTE.

THE following observations on the comet were made at Gottingen, and published there on the 20th of September, 1811:

"The comet which is now visible on the horizon in the northern part of the heavens, is one of the most remarkable which has ever been observed. None has ever been so long visible, and, consequently, none has ever afforded such certain means of information with respect to its orbit. Accordingly, since the end of March last, when it was first perceived by M. Flauguergues in the south of France, its course has been regularly traced; nor shall we lose sight of it till the month of January 1812. Its train, which occupies a space of 12 degrees, exhibits several curious phænomena. It is not immediately connected with the comet, as if it were an emanation from it, but forms, at a distance from the nucleus, a wide belt, the lower part of which girds without coming in contact with it, much in the same manner as the ring of Saturn; and this belt extends itself in two long luminous fasces, one of which is usually rectilinear, while the other, at about the third of its length, shoots forth its rays with a slight curve like the branch of a palm-tree; nevertheless this configuration is subject to change. It has been observed that the space between the body of the comet and its train is occasionally filled, and of the two fasces, that which is generally rectilinear sometimes arches its rays, while those of the other assume the form of right lines. Finally, rays, or, as it were, plumes of ignited matter, have been seen to issue from the lower extremities of the fasces or flakes, and again unite.

"Such fluctuations and accidents in that sort of luminous atmosphere which must occupy in the regions of space a scope of about eight millions of leagues, are immense, and may well impress the imagination with astonishment. The celebrated astronomer of Lilienthal, Mr. De Schrœtter, remarked variations of the same kind in the tail of the last comet of 1807, and inserted, in the work he published with respect to it, plates of the successive configurations.

"Professor Harding has also observed and delineated with care the present comet under its various aspects, and his design will appear in one of the succeeding numbers of the "Geographical and Astronomical Correspondence, edited at the Observatory of Gotha by Mr. De Lindenau.

"They will show that when the comet first appeared, and was yet at a distance from the sun, the two flakes of its train were separated so as to form a right angle; but as that distance decreased, they approached each other till they became parallel. This phenomenon, however, may be nothing more than an optical illusion.

"As to the nucleus, or the comet itself, it has been found impossible, as yet, even with the aid of the best telescopes, to make observations on its disk, as on that of a solid body and of determined circumference. We can only discern a vague circular mass, more luminous than the train, particularly towards the centre; but the verge of which is doubtful, furnishing to the eye no fixed line of demarcation.

"This mass is without doubt composed of a very subtile substance, as is probably that of all comets. This hypothesis receives much support from the fact, that one of these stars, of very considerable magnitude, (the first comet in 1770,) passed and re-passed through the very middle of the satellites of Jupiter without occasioning amongst them the slightest disorder. There is every reason to believe, that the nucleus of the present comet is nothing more than a conglomeration of vapours of very little density, so little perhaps as to be transparent. Whether this be the case or not, might be easily ascertained, if those who are in the habit of observing it would watch the moment of its transit athwart the disk of some star, the rays of which would have sufficient power to perforate it, if transparent. Such a body might very possibly be an incipient world, just past its gaseous state, and which was to derive solidity from the precipitation and condensation of the matter surrounding

it. The successive observation of some comets, in which it may be possible to distinguish the different stages of chaos and progressive formation, can alone furnish any knowledge with respect to this point."

[*Moniteur*, Oct. 4. *Tilloch's* Phil. Mag.]

CHAP. XII.

OBSERVATIONS ON THE PRECEDING PHENOMENON MADE AT THE OBSERVATORY AT GLASGOW.

SIR,

Glasgow Observatory, Oct. 7.

I HOPE the following facts relative to the comet will not be unacceptable to your readers:

Since my communication to you of the 4th, relative to the comet, announcing the determination of the elements of its orbit made at this establishment, I am happy to perceive in the London papers which arrived to-day, the result of Burckhardt's second approximation. The talents of this gentleman as a computor are well known, and highly appreciated by the learned world. Between his time of the perihelion passage and ours there is a difference of no more than three days, and the whole period of the comet's revolution, I am satisfied, exceeds considerably 100 years. It is to be remarked too, that Burckhardt never ventured to give to the public his first trials; and therefore, whatever differences exist between his numbers and ours may have been obtained at his second calculation. The inaccuracy of the first he expressly admits in his letter to the editor of the *Moniteur*, which begins in the following manner:—"Having been requested to correct my first determination," &c. I wish it to be understood, however, that the appearance of his statement has not shaken, in the least degree, the confidence I humbly conceive due to our own results. The observations from which these are derived were performed with the instruments of Troughton; instruments unquestionably superior to any other in the world. But we have still more direct assurance of the accuracy of our observations,

by comparing them with the numbers which have been published from the highest authority (that of the Astronomer Royal) in the Philosophical Magazine. The longitudes of the comet, determined at Greenwich and Glasgow Observatories, coincide to the fraction of a minute.

The time of the perihelion passage may be considered as pretty accurately fixed, either for Sept. 12 or 9, or, as is more probable, at some intermediate period. From this we can fully explain some of the phænomena generally remarked. From the 9th, as stated in the Glasgow papers by a correspondent, the comet was observed to increase considerably both in brilliancy and in the apparent magnitude of the coma, but particularly of the tail, in the course of eight days. This verifies very happily the observation of Sir Isaac Newton, that it is not till immediately after the perihelion passage, that comets acquire their maximum of lustre and of size. The enlargement therefore uniformly takes place at that time, whether the comet is coming nearer us or moving in the opposite direction. The quantity of increase due to its approximation alone, in six or eight days, can be calculated, and we know that there is no instrument in Scotland capable of measuring the change of apparent magnitude produced by this cause. Whether the exquisite micrometer of Troughton, applied to our great Herschelian telescope, may show any difference, I shall be able to ascertain in a few days, as that instrument is lately dispatched from London for us.

I must acknowledge, however, that I entertain very slender hopes of success in this kind of observation on a minute body surrounded with such a nebulosity, and at a distance from us much greater than that of the sun. It has been said, that this comet was ascertained to be the same with that of 1661. The two are as different as can be imagined in every respect. Hence we may see how much safer in the event, scientific investigation is than vague conjectures. I subjoin the elements of the comet of 1661, and those now given by Burckhardt:

	COMET 1661.	BURCKHARDT.
Long. of node	82 deg. 30 min. ...	140 deg. 13 min.
Inclination	32 deg. 35 min. ...	72 deg. 42 min.
Place of perihelion,	115 deg. 58 min. ...	74 deg. 12 min.
Perihelion dist. ...	42,600,000 miles.	96,000,000 miles.

I am, Sir, your obedient servant,

ANDREW URE.

Glasgow Observatory, Oct. 16.

SIR—In the Glasgow Courier of October 5, I had the honour of submitting to the public the results of the joint labours of Mr. Cross and myself, for the preceding month, on the comet, at the Glasgow Observatory. In The Star newspaper of October 11, appeared for the first time the elements of the orbit, as determined by the celebrated Burckhardt, Member of the National Institute.

It is a duty which I owe to the skill and the unwearied exertions of my associate Mr. Cross, to this patriotic establishment, and also to this country, hitherto considered by the French mathematicians and astronomers unequal to the primary solution of this difficult problem, to state the following facts:—On October 8, at eight hours fifteen minutes, by observations made here, with every precaution to insure the utmost accuracy, the comet had deviated 42 degrees 18 minutes from the longitude which Burckhardt's elements assign for that instant. On October 14, at two o'clock in the morning, the longitude, as deduced from a most satisfactory transit, was 206 degrees 42 minutes. By the French computation it ought to have been 248 degrees 1 minute, differing from nature by 41 degrees 19 minutes. By our elements, which have received a partial correction from my observations since the 5th, the coincidence on the 8th, at the same time, was within 15 minutes, and on the 14th, within 13 minutes. Our computed latitudes on the 13th agree to a minute with observation, while those of Burckhardt differ by 3 degrees or 180 times that quantity.

The examination of both has been made by the excellent tables of the parabola, constructed by Delambre, imperial observer at Paris. It is in the longitude of the perihelion that the chief discordance exists between the French elements and ours, and this amounts to about 31 degrees; the former being, in our judgment, too small by this quantity.

The comet has been continually approaching the earth for many weeks. From September 15th till October 14th, its decrease of distance amounted to 25 millions of miles, yet its brilliancy and the magnitude of its tail have gone on diminishing, as Burckhardt properly remarked. Persons ignorant of astronomy would naturally infer from this diminution the recedure of the comet from us, as, from its increase they conjectured its approach. Astronomers laugh at such idle dreams when applied to a demonstrative science, in

which conjecture has found no place since the days of Newton. Its first principles teach, that these phænomena arise from the comet's varying distance from the sun. At the period of the perihelion passage these bodies are known uniformly to attain their maximum of size and brightness.

ANDREW URE.

[*Tilloch's* Phil. Mag.]

CHAP. XIII

OF SOLAR AGENCY IN THE PRODUCTION OF COMETIC PHÆNOMENA.

As we are now in a great measure acquainted with the physical construction of the different parts of the present comet, and have seen many successive alterations that have happened in their arrangement, it may possibly be within our reach to assign the probable manner in which the action of such agents as we are acquainted with has produced the phænomena we have observed.

In its approach to a perihelion, a comet becomess exposed to the action of the solar rays, which, we know are capable of producing light, heat, and chemical effects. That their influence on the present comet has caused an expansion, and decomposition of the cometic matter, we have experienced in the growing condition of the tail and shining quality of its light, which seems to be of a phosphoric nature. The way by which these effects have been produced may be supposed to be as follows.

The matter contained in the head of the comet would be dilated by the action of the sun, but chiefly in that hemisphere of it which is immediately exposed to the solar influence; and being more increased in this direction than on the opposite side, it would become eccentric, when referred to the situation of the body of the comet; but as the head is what draws our greatest attention, on account of

its brightness, the little planetary body would appear to be in the excentric situation in which we have seen it.

Now, as from observed phænomena, we have good reason to believe the comet to be surrounded by a very extensive, transparent, elastic atmosphere; the nebulous matter, which probably, when the comet is at a distance from the perihelion, is gathered about the head in a spherical form, would on its approach to the sun be greatly rarefied, and rise in the cometic atmosphere till it came to a certain level, where it could remain suspended, for some time, exposed to the continued action of the sun.

In this situation we have had an opportunity of seeing the transparent atmosphere, which, but for the suspension of the nebulous matter, we might never have discovered; and indeed, how far it may extend beyond the region which contained the shining substance, we can have no observation to ascertain, on account of its transparency. In consequence of the darkish interval, occasioned by the atmospheric space, the suspended light appeared to us in the shape of a very bright envelope.

The brilliancy of the envelope, and its yellowish colour, so different from that of the head, and probably acquired by its mixture with the atmospheric fluid, are proofs of the continued action of the sun upon the luminous matter, already in so high a state of rarefaction; and if we suppose the attenuation and decomposition of this matter to be carried on till its particles are sufficiently minute to receive a slow motion from the impulse of the solar beams, then will they gradually recede from the hemisphere exposed to the sun, and ascend in a very moderately diverging direction towards the regions of the fixed stars.

That some such operation must have been carried on, is pretty evident from our having seen the gradual rise, and increased expansion of the tail of the comet; and if we saw the shining matter, while suspended in the cometic atmosphere, in the shape of an envelope, it follows that, in its rising condition, it would assume the appearance of those two luminous branches which we have so long observed to inclose the tail of the comet.

The seemingly circular form, and the stream-like appearance of the luminous matter, having been already explained, we may now see the reason why it can rise in no other form than the conical; for

a whole hemisphere of it being exposed to the action of the sun, it must of course ascend equally every where all around it.

That the luminous matter ascending in the hollow cone, received no addition to its quantity from any other source than the exposed hemisphere, we may conclude from its appearance; which notwithstanding the great circumference of the cone it filled, at the altitude of 6 degrees from the head, was never seen with increased lustre; although the diameter of an annular section of it, in that place, must have been nearly 15 millions of miles, and was but little more than half a million at its rising from the envelope.

This consideration points out the extreme degree of rarefaction of the luminous matter about the end of the tail; for its expansion while still much confined in the streams, at the altitude which has been mentioned, must have exceeded the density it had at rising about 524 times; but when afterwards it extended itself so as to produce nearly an evenly scattered light over the whole compass of the end of the tail, we may easily conceive to what an extreme degree of rareness its expansion must have been carried.

The vacancy occasioned by the escape of the nebulous matter, which after rarefaction passed from the hemisphere exposed to the sun into the regions of the tail, was probably filled up, either by a succession of it from the opposite hemisphere, or by a rotation of the comet about an axis; and the gradual decomposition of this matter would therefore be carried on as long as any remained to replace the deficiency.

That such a kind of process took place, seems to be supported by the observations which were made during the regression of the comet from its perihelion. For the space between the branches of the tail, very near the head of the comet, became gradually of a darker appearance than before; which indicated the absence of the nebulous matter that had formerly been lodged there.

A rotatory motion of the comet, which has been suggested, would also explain the frequent variations in the length of the opposite branches which inclosed the tail; for if any portion of the cometary matter should be more susceptible of being thrown into a luminous decomposition than some others, a rotatory motion would bring such more susceptible matter into different situations, and cause a more or less copious emission of it in different places.

The additional short and faint double streams of nebulous light which issued from the vertex or side of the enfeebled envelope, in the gradual regress of the comet, tend likewise to add probability to the conception of a rotatory motion; for the changeable appearance of the situation of these streamlets might arise from a periodical exposition of some remaining small portions of less rarefied matter, when nearly the whole of it had been exhausted.

[*Herschel*, Phil. Trans. 1812.]

CHAP. XIV.

ON THE RESULT OF A COMET'S PERIHELION * PASSAGE.

After having given a detail of phænomena, and entered into a research of the most likely manner in which they were produced, I shall only mention what appears to me to be the most probable consequence of the perihelion passage of a comet.

The quality of giving out light, although it may always reside in a comet, as it does in the immensity of the nebulous matter, which I have shown to exist in the heavens, is exceedingly increased by its approach to the sun. Of this we should not be sensible, if it were not accompanied with an almost inconceivable expansion and rarefaction of the luminous substance of the comet about the time of its perihelion passage.

It is admitted, on all hands, that the act of shining denotes a decomposition in which at least light is given out; but that many other elastic volatile substances may escape at the same time, especially in so high a degree of rarefaction, is far from improbable.

Then, since light certainly, and very likely other subtile fluids,

* The passage in which it approaches nearest to the sun: in which sense the term stands opposed to *aphelion*, constituting the comet's highest or most distant point from the sun.—Editor.

also escape in great abundance during a considerable time before and after a comet's nearest approach to the sun, I look upon a perihelion passage in some degree as an act of consolidation.

If this idea should be admitted, we may draw some interesting conclusions from it. Let us, for example, compare the phænomena that accompanied the comet of 1807 with those of the present one. The first of these in its approach to the sun came within 61 millions of miles of it; and its tail, when longest, covered an extent of 9 millions. The present one in its perihelion did not come so near the sun by nearly 36 millions of miles, and nevertheless acquired a tail 91 millions longer than that of the former. The difference in their distances from the earth when these measures were taken was but about 2 millions.

Then may we not conclude, that the consolidation of the comet of 1807, when it came to the perihelion, had already been carried to a much higher degree than that of the present one, by some former approach to our sun, or to other similarly constructed celestial bodies, such as we have reason to believe the fixed stars to be?

And that comets may pass round other suns than ours, is rendered probable from our knowing as yet, with certainty, the return of only one comet among the great number that have been observed.

Since then, from what has been said, it is proved that the influence of the sun upon our present comet has been beyond all comparison greater than it was upon that of 1807; and since we cannot suppose our sun to have altered so much in its radiance as to be the cause of the difference; have we not reason to suppose that the matter of the present comet has either very seldom, or never before passed through some perihelion by which it could have been so much condensed as the preceding comet? Hence may we not surmise *that* the comet of 1807 was more advanced in maturity than the present one; that is to say, that it was comparatively a much older comet.

Should the idea of age be rejected, we may indeed have recourse to another supposition, namely, that the present comet, since the time of some former perihelion passage, may have acquired an additional quantity (if I may so call it) of *unperihelioned* matter, by moving in a parabolical direction through the immensity of space,

and passing through extensive strata of nebulosity; and that a small comet, having already some solidity in its nucleus, should carry off a portion of such matter, cannot be improbable. Nay, from the complete resemblance of many comets to a number of nebulæ I have seen, I think it not unlikely that the matter they contain is originally nebulous. It may therefore possibly happen that some of the nebulæ, in which this matter is already in a high state of condensation, may be drawn towards the nearest celestial body of the nature of our sun; and after their first perihelion passage round it proceed, in a parabolic direction, towards some other similar body; and passing successively from one to another, may come into the regions of our sun, where at last we perceive them transformed into comets.

The brilliant appearance of our small comet may therefore be ascribed either to its having but lately emerged from a nebulous condition, or to having carried off some of the nebulous matter, situated in the far extended branch of its parabolic motion. The first of these cases will lead us to conceive how planetary bodies may begin to have an existence; and the second, how they may increase, and, as it were, grow up to maturity. For if the accession of fresh nebulous matter can be admitted to happen once, what hinders us from believing a repetition of it probable? and in the case of parabolic motions, the passage of a comet through immense regions of such matter is unavoidable.

[*Herschel*, Phil. Trans. 1812.]

CHAP. XV.

GENERAL REMARKS ON THE PRECEDING CHAPTERS RELATIVE TO COMETS.

It is manifest from Chapter X, that Dr. Herschel supposes the comet of 1811 to have been produced from nebulous light, consistently with his theory noticed in chapters VII and VIII; that such light became progressively consolidated, and that a part of its luminous matter had been exhaled in its approach to some other stars before its perihelion path in our own system. Yet from the length of its tail, and the luminous envelope that surrounded its outer line, compared with those of the comet of 1807, he thinks it must have been of much later date.

The comet of 1807, in its approach to the sun advanced within sixty-one millions of miles of it, and its tail, when longest, covered an extent of nine millions of miles. The late comet, in its perihelion did not pass so near the sun by about thirty-six millions of miles, being about two thirds only of the closest approximation of the preceding, and nevertheless acquired a tail of upwards of a hundred millions of miles. May we not then conclude, as he suggests, that the consolidation of the comet of 1807, when it reached its perihelion, had already been carried to a much greater degree of density than that of the last comet, by some former approach to our sun, or to some similarly constructed celestial bodies, such as we have reason to believe the fixed stars to be? And that comets may pass round other suns than ours, is rendered probable from our not knowing, with certainty as yet, the return of more than one comet among the great number that have been observed?

He calculates the bright point, or what we may admit to be the solid or planetary body of the comet, at about 428 miles in diameter: and that its distance from the earth, at the time of making his observations, was 114 millions of miles. It existed in a stelliform nucleus which he calls the head of the comet, the diameter of which he calculates at 127 thousand miles. It was surrounded by

a circular darkish space which he supposes to be an atmosphere, and computes at 507 thousand miles in diameter. The tail varied in length and breadth from September 2, when he could perceive none, to September 9, when it extended 9 or 10 degrees; September 18, when it reached 11 or 12 degrees; October 6, at which it possessed 25 degrees, which was its greatest length. On October 12, it was 17 degrees, and on October 15, 23½ degrees, or somewhat more than a hundred million of miles. The breadth of the tail varied as well as its length; on October 12, it was 6⅓ degrees in its broadest part, or nearly 15 millions of miles.

The general shape of the comet he calculates must have been that of an inverted hollow cone, terminating its vertex in an equally hollow cap of nearly an hemispherical construction; the cap and sides of this hollow cone being of inconsiderable thickness. The tail shortened rapidly in November. On the 5th it was 12¼ degrees; on the 16th 7¼, December 10th 5 degrees, and of feeble light; on the 14th nearly the same, but the light very considerably feebler.

To these remarks we may farther add, that the tail of the comet of 1680, was nearly equal to that of 1811, having been calculated at a hundred millions of miles.

Deguignes enumerates two or three hundred comets mentioned by Chinese writers. Doubts, however, have since been thrown upon the authorities referred to.

Extensive as are orbits of comets, from their eccentricity they have sometimes approached much nearer to the sun than any of the planets; for the comet of 1680, when at its perihelion, was at the distance of only one-sixth of the sun's diameter from its surface. Yet from the very inconsiderable density of their enormous tails, and even of the greater part of the nucleus itself, should it ever happen to a planet, of which there is but very little probability, to fall exactly in the way of a comet, it is supposed that the inconvenience suffered by the inhabitants of the planet might be merely temporary and local: the chances are, however, much greater, that a comet might interfere in such a manner with a planet, as to deflect it a little from its course, and retire again without coming actually into contact with it.

Nearly 500 comets are recorded to have been seen at different times, and the orbits of about a hundred have been correctly as-

certained: but we have no opportunity of observing a sufficient portion of the orbit of any comet, to determine with accuracy the whole of its form as an ellipsis, since the part which is within the limits of our observation does not sensibly differ from the parabola, which would be the result of an ellipsis prolonged without end.

Two comets at least, or perhaps three, have been recognized in their return. A comet appeared in 1770, which Prosperin suspected to move in an orbit materially different from a parabola; Mr. Lexell determined its period to be 5 years and 7 months, and its extreme distances to be between the orbits of Jupiter and of Mercury; but it does not appear that any subsequent observations have confirmed his theory. It has, however, been calculated, that supposing the theory correct, it must afterwards have approached so near to Jupiter as to have the form of its orbit entirely changed.

Dr. Halley foretold the return of a comet about 1758, which had appeared in 1531, in 1607, and in 1682, at intervals of about 75 years; and with Clairaut's further correction for the perturbations of Jupiter and Saturn, the time agreed within about a month. The mean distance of this comet from the sun must be less than that of the Georgian planet; so that by improving our telescopes still more highly, we may, perhaps, hereafter be able to convert some of the comets into planets, so far as their remaining always visible would entitle them to the appellation. Dr. Halley also supposed the comet of 1680 to have been seen in 1106, in 531, and in the year 44 before Christ, having a period of 575 years; and it has been suspected that the comets of 1556 and 1264 were the same, the interval being 292 years; a conjecture which will either be confirmed or confuted in the year 1848. Some persons have even doubted of the perfect coincidence of the orbits of any comets, seen at different times, with each other, and have been disposed to consider them as messengers forming a communication between the neighbouring systems of the sidereal world, and visiting a variety of stars in succession, so as to have their courses altered continually, by the attraction towards many different centres; but considering the coincidence of the calculation of Halley and Clairaut with the subsequent appearance of the comet of 1759, this opinion can scarcely be admitted to be in any degree probable with respect to the comets in general, however possible the supposition may be in some particular cases.

The reader may upon this subject consult also *Bartholinus* De Cometis, 4to.Copenhagen, 1665; *Hooke's* Lectures and Collections, 4to. 1678; Cometa,—Figures, p. 2, 3; *Heinsius*, Ueber den Cometen, 4to. Petersb. 1743; *Dionis du Séjour*, Essai sur les Cometes, Paris, 1775; *Deguignes*, S. E. X. 1785. App. 39; *Young's* Nat. Phil. Vol. I. p. 513.

CHAP. XVI.

SYNOPSIS OF THE PRINCIPAL ELEMENTS OF ASTRONOMY, DEDUCED FROM M. LA PLACE'S EXPOSITION DU SYSTEME DU MONDE.

THE following article is drawn from the third edition of M. La Place's very excellent *Exposition* (1808) in which the author has given the elements of the planets in a more correct manner than in either of the preceding editions; and wherein he has revised and amended all his former calculations by more recent and exact observations.

The arrangement of the present memoir is somewhat new; but many persons have frequently found the want of a manual of this kind, where all the different facts, relative to astronomy, might be brought under their respective heads, without the necessity of turning to a variety of works for information. Much time is often lost in a research of that kind, which it is the object of the present abstract to prevent.

In the original work, the author has universally adopted the decimal division of the day, and of the quadrant. This method is here preserved in the Tables of the Elements of the Planets; but, in subsequent parts, the common sexagesimal notation is adopted, as being more easily understood in this country.

Some other facts, not mentioned by M. La Place, are inserted in this tract, in order to enlarge the view of the subject: but these passages are always kept separate, by being inclosed within brackets.

The Sun.

The Sun, which is the source of light and heat to our system, is the most considerable of all the heavenly bodies, and governs all the planetary motions.

Its diameter is 111·454 times the mean diameter of the earth; whence its volume is 1384472 times greater than that of the earth; but its mass is only 337086 times greater. Whence we conclude that its density is $\frac{1}{3\cdot 9326}$, or about $\frac{1}{4}$ that of our globe.

It is surrounded by an atmosphere; and it is oftentimes covered with spots. Some of these spots have been observed so large as to exceed the earth four or five times in magnitude.

The observation of these spots shows that the Sun moves on its axis, which is nearly perpendicular to the ecliptic; and the duration of an entire sidereal rotation of the sun is about $25\frac{1}{2}$ days.

Whence we conclude that the sun is flattened at the poles.

The solar equator is inclined 7° 30′ to the plane of the ecliptic.

A body, which weighs one pound at the surface of the earth, would, if removed to the surface of the sun, weigh 27·933 pounds. And bodies would fall there with a velocity of 334·65 feet in the first second of time.

The sun, together with the planets, moves round the common centre of gravity of the system; which centre is nearly in the centre of the sun.

This motion changes into epicycloids the ellipses of the planets and comets, which revolve round the sun.

The sun appears to have a particular motion, which carries our system towards the constellation of Hercules.

The apparent diameter of the sun, as seen from the earth, undergoes a periodical variation. It is greatest when the earth is in its perihelion; at which time it is 32′ 35″,6: and it is least when the earth is in its aphelion; at which time it is 31′ 31″,0. Its mean apparent diameter is therefore 32′ 3″,3.

His horizontal parallax is $8\frac{3}{4}$″.

The greatest equation of his centre is 1° 55′ 27″,7; which diminishes at the rate of 16″,9 in a century.

The diurnal motion of the sun from east to west, and his annual motion in the ecliptic, are optical deceptions; arising from the real motion of the earth on its axis, and in its orbit.

The Planets.

The number of planets belonging to our system is eleven. Six of these have been known and recognised from time immemorial: namely, Mercury, Venus, the Earth, Mars, Jupiter and Saturn. But the remaining five, which are not visible to the naked eye, have lately been discovered by the help of the telescope; and are therefore called telescopic planets: namely,

Uranus, discovered by	Dr. Herschel,	March 13, 1781.
Ceres	M. Piazzi, ..	January 1, 1801.
Pallas, ...	M. Olbers, ..	March 28, 1802.
Juno, ...	M. Harding, ..	Septem. 1, 1803.
Vesta, ...	M. Olbers, ..	March 29, 1807.

All these planets revolve round the sun, as the centre of motion: and in performing their revolutions they follow the fundamental laws of the planetary motion so happily discovered by Kepler; and which have been fully confirmed by subsequent observations. These laws are,

I. The orbit of each planet is an ellipse; of which the sun occupies one of the foci.

The extremity of the major axis of this ellipse, nearest the sun, is called the perihelion; the opposite extremity of the same axis is called the aphelion. The line, which joins these two points, is called the line of the apsides. The radius vector is an imaginary line drawn from the centre of the sun to the centre of the planet, in any part of its orbit.

The velocity of a planet in its orbit is always greatest at its perihelion. This velosity diminishes as the radius vector increases; till the planet arrives at its aphelion, when its motion is the slowest. It then increases, in an inverse manner, till the planet arrives again at its perihelion.

II. The areas, described about the sun by the radius vector of the planet, are proportional to the times employed in describing them.

These laws are sufficient for determining the motion of the planets round the sun; but it is necessary to know, for each of these planets, seven quantities; which are called the elements of their elliptical motion. The first five of these elements relate to the motion in an ellipse; the last two relate to the position of the orbit; since the planets do not all move in the same plane.

1. The duration of a sidereal revolution of the planet.

2. Half the major axis of the orbit; or the mean distance of the planet from the sun.

3. The eccentricity of the orbit; whence we deduce the greatest equation of the centre.

4. The mean longitude of the planet at a given epoch.

5. The longitude of the perihelion at a given epoch.

6. The longitude of the nodes at a given epoch.

7. The inclination of the orbit to the ecliptic.

The following Tables present all these elements for the first moment of the present century; namely, for that point of time at midnight which separates the 31st of December 1800, and the 1st of January 1801 mean time at Paris.—[The observatory at Paris is in north latitude 48° 50′ 14″, and in longitude 9′ 21″ east from Greenwich observatory.]

1. *Duration of a Sidereal Revolution.*

	days.		days.
Mercury	87·96925804	Ceres	1681·53900000
Venus	224·70082399	Pallas	1681·70900000
Earth	365·25638350	Jupiter	4332·59630760
Mars	686·97961860	Saturn	10758·96984000
Vesta	1335·20500000	Uranus	30688·71268720
Juno	1590·99800000		

2. *Mean Distance from the Sun.*

Mercury	·3870981	Ceres	2·7674060
Venus	·7233323	Pallas	2·7675920
Earth	1·0000000	Jupiter	5·2027911
Mars	1·5236935	Saturn	9·5387705
Vesta	2·3730000	Uranus	19·1833050
Juno	2·6671630		

3. *Ratio of the Eccentricity to half the Major Axis.*

Mercury	·20551494	Ceres	·07834860
Venus	·00685298	Pallas	·24538400
Earth	01685318	Jupiter	·04817840
Mars	·09313400	Saturn	·05616830
Vesta	·09322000	Uranus	·04667030
Juno	·25494400		

4. *Mean Longitude, January* 1, 1801.

Mercury	182° 15647	Ceres	294° 16820
Venus	11° 93672	Pallas	280° 68580
Earth	111° 28179	Jupiter	124° 67781
Mars	71° 24145	Saturn	150° 38010
Vesta	297° 12990	Uranus	197° 54244
Juno	322° 79380		

5. *Mean Longitude of the Perihelion.*

Mercury	82° 6256	Ceres	162° 9565
Venus	142° 9077	Pallas	134° 7040
Earth	110° 5571	Jupiter	12° 8812
Mars	369° 3407	Saturn	99° 0549
Vesta	277° 4630	Uranus	185° 9574
Juno	59° 2349		

6. *Longitude of the ascending Node.*

Mercury	51° 0651	Ceres	89° 9083
Venus	83° 1972	Pallas	191° 7148
Earth	0° 0000	Jupiter	109° 3624
Mars	53° 3605	Saturn	124° 3662
Vesta	114° 4630	Uranus	80° 9488
Juno	190° 1228		

7. *Inclination of the Orbit to the Ecliptic.*

Mercury	7° 78058	Ceres	11° 80680
Venus	3° 76936	Pallas	38° 46540
Earth	0° 00000	Jupiter	1° 46034
Mars	2° 05663	Saturn	2° 77102
Vesta	7° 94010	Uranus	0° 85990
Juno	14° 50860		

The examination of the first two tables here given will show us that the duration of the revolutions of the planets increases with their mean distance from the sun. Whence Kepler discovered his third fundamental law; namely,

III. The squares of the times of the revolutions of the planets are to each other as the cubes of their mean distances.

The ellipses, which the planets describe, however, are not unalterable. Their major axes appear to be always the same; but their eccentricities, the positions of their perihelion and nodes, together with the inclination of their orbits to the ecliptic, seem to vary in a

course of years. These variations, being sensible only in a series of ages, are called secular inequalities. There is no doubt of their existence; but the modern observations not being sufficiently extensive, and the ancient not sufficiently exact, there still rests some degree of uncertainty as to their magnitude. The following Table will show the inequalities that happen in a period of one hundred years, and are the values that appear to accord best with the present observations.

SECULAR INEQUALITIES OF THE PLANETS.

The sign — signifies a Diminution.

Planets.	In the Eccentricity.	In the Perihelion.	In the Inclination.	In the Place of Nodes
Mercury	·000003867	0° 180110	0° 005612	—0° 241441
Venus ..	—·000062711	—0° 082663	—0° 001405	—0° 577099
Earth ..	—·000041632	0° 364140	....	....
Mars ..	·000090176	0° 488405	—0° 000447	—0° 718665
Jupiter ..	·000159350	0° 204895	—0° 006978	—0° 486904
Saturn ..	—·000312402	0° 597860	—0° 004788	—0° 699525
Uranus ..	—·000025072	0° 073869	0° 000967	—1° 110481

There are also some inequalities which affect the elliptical motion of the planets. That of the earth is a little altered. But they are most sensible in Jupiter and Saturn; for it appears that the duration of their revolution round the sun is subject to a periodical variation.

Mercury.

Mercury is the nearest planet to the sun; its mean distance being ·387, that of the earth being considered as unity. This makes his mean distance above 36 millions of miles.

He performs his sidereal revolution in 87 23^h 15′ 43″,9 and his mean synodical revolution in about 116 days.

The eccentricity of his orbit is ·2055; half the major axis being taken as equal to unity.

His mean longitude, at the commencement of the present century, was in 5^s 23° 56′ 27″,0.

The longitude of his perihelion was, at the same time, in 2^s 14° 21′ 46″,9. The line of the apsides has a sidereal motion, according to the order of the signs, equal to 9′ 43″,6 in a century. But, if referred to the ecliptic, this motion will (owing to the precession of

the equinoctial points) be equal to 55″,8 in a year; or to 1° 33′ 13″,6 in a century.

His orbit is inclined to the plane of the ecliptic in an angle of 7° 0′ 9″,1; which angle is subject to a small increase of about 18″,2 in a century.

His orbit, at the commencement of the present century, crossed the ecliptic in 1^s 15° 57′ 30″,9; having a sidereal motion to the westward every century, of 13′ 2″,2. But, if referred to the ecliptic, the place of the nodes will (on account of the precession of the equinoxes) fall more to the eastward by 42″,3 in a year, or 1° 10′ 27″,8 in a century.

The rotation on his axis is accomplished in 1^d 0^h 5′ 28″,3. But the inclination of its axis is not known.

[The diameter of Mercury is about 3123 miles; which, compared with the earth's diameter considered as unity, is about ·3944·]

His mass, compared with that of the sun considered as unity, is $\frac{1}{2025810}$.

[The proportion of light and heat received from the sun is about 6·68 times greater than on our planet.]

As seen from the earth, Mercury never appears at any great distance from the sun; either in the morning or the evening. His elongation, or angular distance, varies from 16° 12′ to 28° 48′.

His course sometimes appears retrograde. The mean arc, which it describes in this case, is about 13° 30′; and its mean duration is about 23 days; but there is great difference in this respect. This retrogradation commences or finishes when he is about 18° distant from the sun.

Mercury changes his phases, like the moon, according to his various positions with regard to the earth and sun: but this cannot be discovered without the aid of a telescope. His mean apparent diameter is 6″,9.

[Mercury is sometimes seen to pass over the sun's disk; which can only happen when he is in his nodes, and when the earth is in the same longitude. Consequently this phænomenon can take place only in the month of May or November. The first observation of this kind was made by Gassendi in November 1631; since which period they have been frequent. The next appearance of this kind will be in November 1815.]

Venus.

Venus performs her sidereal revolution in 224^d 16^h 49′ 11″,2; and her mean synodical revolution is about 584 days.

Her mean distance from the sun is ·723; that of the earth being considered as unity. This makes her mean distance nearly 68 millions of miles.

The eccentricity of her orbit is ·0069; half the major axis being considered as unity. She is the least eccentric of all the planets.

Her mean longitude, at the commencement of the present century, was in 0^s 10° 44′ 35″,0.

The longitude of her perihelion was, at the same time, in 4^s 8° 37′ 0″,0. The line of her apsides has a sidereal motion, contrary to the order of the signs, of 4′ 27″,8 in a century. But if referred to the ecliptic, this motion will appear (on account of the precession of the equinoxes) to proceed according to the order of the signs at the rate of 47″,4 in a year, or 1° 19′ 2″,2 in a century.

Her orbit is inclined to the plane of the ecliptic in an angle of 3° 23′ 32″,7; which angle decreases about 4″,6 in a century.

Her orbit, at the commencement of the present century, crossed the ecliptic in 2^s 14° 52′ 38″,9. But the nodes have an apparent motion in longitude of 31″,4 in a year, or 52′ 20″,2 in a century.

The rotation on her axis is performed in 23^h 21′ 7″,2; but the inclination of her axis is not known.

[The diameter of Venus is 7702 miles: consequently she is nearly as large as the earth.]

Her mass, compared with that of the sun considered as unity, is $\frac{1}{356632}$.

[The proportion of light and heat, received by her from the sun, is 1·91 times greater than on our planet.]

It is surrounded by an atmosphere, the refractive powers of which differ very little from those of our atmosphere.

As viewed from the earth, Venus is the most brilliant of all the planets: and may sometimes be seen with the naked eye at noon day. She is known as the morning and evening star; and never recedes far from the sun. Her elongation, or angular distance, varies from 45° to 48°.

Her motion sometimes appears retrograde. The mean arc, which she describes in such case, is about 16° 12′; and her mean duration

is about 42 days. This retrogradation commences, or finishes, when she is about 28° 48′ distant from the sun.

Venus changes her phases, like the moon, according to her position with respect to the sun and the earth: which causes a very considerable difference in her brilliancy.

Her mean apparent diameter is 17″,0; her greatest apparent diameter is about 57″,3.

[Venus is sometimes seen to pass over the sun's disk; which can happen only when she is in her nodes, and when the earth is in the same longitude. Consequently it can take place only in the months of June or December. Three of these transits have been already observed: one in 1639, one in June 1761, and one in June 1769. There will not be another till the 8th of December 1874.]

The Earth.

The Earth which we inhabit is also one of the planets that revolve about the sun. It performs its sidereal revolution in $365^d\ 6^h\ 9'\ 11'',5$: but the time employed in going from one tropic to the other is only $365^d\ 5^h\ 48'\ 51'',6$. The tropical year is about 11″,2 shorter than it was at the time of Hipparchus.

Its mean distance from the sun is 23578 times its own semi-diameter: whence it is above 93 millions of miles distant from that luminary. If this mean distance be taken equal to unity, we shall have its distance at the perihelion equal to ·9832; and its distance at the aphelion equal to 1·0168.

The eccentricity of its orbit is ·0168: half the major axis being considered as unity. The major axis, therefore, will be to the minor axis of the orbit, in the proportion of 1 to ·99439.

Its mean longitude, at the commencement of the present century, was $3^s\ 10^\circ\ 9'\ 13'',0$.

Its velocity varies in different parts of its orbit. Like all the other planets, it is most rapid in its perihelion, and slowest in its aphelion. In the former point it describes an arc of 1° 1′ 9″,9 in the course of a day; and in the latter point it describes an arc of only 57′ 11″,5 in the same period. The mean velocity is 59′ 0″,7 each day.

The mean longitude of its perihelion at the commencement of the present century was $3^s\ 9^\circ\ 30'\ 5'',0$. But the line of the apsides has a direct sidereal motion of 19′ 40″,8 in a century; which,

being referred to the ecliptic, will give it a motion (according to the order of the signs) of 1′ 1″,9 in a year, or 1° 43′ 10″,8 in a century. A complete revolution round the line of the apsides is called the anomalistic year; and is performed in $365^d\ 6^h\ 14'\ 2''$. The perihelion coincided with the vernal equinox about the year 4089 before the Christian æra. It coincided with the summer solstice about the year 1250 after Christ; and will coincide with the autumnal equinox about the year 6483. A complete tropical revolution of the apsides is performed in 20931 years.

The axis of the earth is inclined to the plane of the ecliptic in an angle of 23° 27′ 57″,0; which angle is observed to decrease at the rate of 52″,1 in a century. But this variation of the angle is confined within certain limits; and cannot exceed 2° 42′.

The annual intersection of the equator with the ecliptic is not always in the same point: but is retrograde, or contrary to the order of the signs. Consequently the equinoxial points appear to move forward on the ecliptic; and whence this phenomenon is called the precession of the equinoxes. The quantity of this annual change is 50″,1; or 1° 23′ 30″ in a century. A complete revolution is performed in 25868 years.

The sidereal day, or the time employed by the earth in revolving on its axis, is always the same. Its diurnal rotation has not varied the hundredth part of a second, since the time of Hipparchus. If the mean astronomical, or civil, day be taken equal to 24 hours, the duration of the sidereal day will be $23^h\ 56'\ 4'',1$.

The astronomical, or civil, day is constantly changing. This variation arises from two causes; 1. The unequal motion of the earth in its orbit; 2. The obliquity of that orbit to the plane of the equator. [The mean and apparent solar days are never equal, except when the sun's daily motion in right ascension is 59′ 8″. This is the case about April 16th, June 16th, September 1st, and December 25th; on these days the difference vanishes, or nearly so. It is at its greatest about November 1st, when it is 16′ 16″.]

The astronomical year is divided into four parts, determined by the two equinoxes and the two solstices. The interval between the vernal and autumnal equinoxes is (on account of the eccentricity of the earth's orbit, and its unequal velocity therein) near eight days

longer than the interval between the autumnal and vernal equinoxes. These intervals are, at present, nearly as follow:

	d. h. m.	d. h. m.
From the spring equinox to the summer solstice	92 21 45	=185 35 20
From the summer solstice to the autumnal equinox	93 13 35	
From the autumnal equinox to the winter solstice	89 16 47	=178 18 29
From the winter solstice to the spring equinox	89 1 42	
		7 16 51

The nutation of the earth's axis is 19″,3.

Light takes 8′ 13″,3 to come from the sun to the earth. But in this interval the earth has moved 20″,2 in its orbit. This motion of the earth produces an optical illusion in the light which comes from the stars; and which Bradley calls the aberration of light.

The figure of the earth is that of an oblate spheroïd; the axis of the poles being to the diameter of the equator as 331 to 332. The mean diameter of the earth is about 7916 miles; its equatorial diameter is 7924 miles.

As a necessary consequence from this circumstance, the degrees of latitude increase in length as we recede from the equator to the poles. But different meridians, under the same latitude, present different results. The general fact, however, is well ascertained.

The density of the earth is 3·9326 times greater than that of the sun, and is to that of water as 11 to 2.

Its mass, compared with that of the sun considered as unity, is $\frac{1}{337086}$.

The centrifugal force is greater at the equator than at the poles: in consequence of which, bodies lose part of their weight by being taken towards the equator. If the gravity of a body at the equator be represented by unity, its gravity at the poles will be increased by ·00569. A pendulum, therefore, which vibrates seconds in the higher latitudes, must be shortened at the equator in order to render the oscillations isochronous. [A pendulum 39·197 inches long will swing seconds at the poles; but, in order that it may swing seconds at the equator it must be reduced to 39·027 inches.]

The centrifugal force at the equator is nearly $\frac{1}{289}$th of gravity.

If the rotation of the earth were 17 times more rapid, the centrifugal force would be equal to that of gravity; and bodies at the equator would not have any weight.

A rare and elastic fluid surrounds the earth, which is called the atmosphere. Neither the temperature nor the density of this fluid is uniform; but diminishes in proportion to its distance from the surface of the earth, and is also affected by other circumstances.

If the density of the atmosphere were every where the same, and its temperature at zero, and the height of the barometer at 29·92196 inches, the height of the atmosphere would be 26067 feet; or 3·7 miles.

The atmosphere is a heterogeneous substance. Out of 100 parts, 79 are azotic gas, and the remaining 21 are oxygen gas. This is found to be universally the case, in whatever season or whatever climate the experiment be tried. This proportion is also found to exist in the highest points of the asmosphere that have been reached by means of balloons.

A body projected horizontally to the distance of about 4·35 miles, if there were no resistance in the atmosphere, would not fall again to the surface of the earth, but would revolve round it as a satellite; the centrifugal force being there equal to its gravity.

The rays of light do not move in a straight line through the atmosphere; but are inflected continually towards the earth: so that the stars appear more elevated on the horizon than they really are.

We find, from the most accurate observations, that the refraction, which the atmosphere produces, is independent of its temperature, and proportional to its density. But, as the density varies according to the temperature; it is necessary to attend not only to the state of the barometer, but also of the thermometer.

The humidity of the air produces very little effect on its refractive powers, and may therefore be safely omitted.

The temperature of the whole atmosphere being supposed at zero, its density will diminish in a geometrical progression, according to its distance from the surface of the earth: and we find by experience, that the height of the barometer being 29·92 inches, the refraction at the horizon is 39′ 54″,7. It would be only 30′ 24″,1 if its density diminished in arithmetical progression; and would be nothing at the surface. The horizontal refraction, which we observe about 35′ 0″,0 is a mean between these limits.

When the apparent height of a star upon the horizon does not exceed eleven degrees, its sensible refraction depends only on the state of the barometer and thermometer in the place of observation; and it is nearly proportional to the tangent of the apparent distance of the star from the zenith, diminished by 3¼ times the corresponding refraction at this distance, the thermometer being considered as at the freezing point and the barometer as at 29·92 inches. From these principles have been formed the Tables of Refraction, corresponding to the several variations in the scale of the thermometer and barometer.

The action of the sun and moon has a considerable effect on the water of the ocean, and produces the phænomena of the tides.

The sea rises and falls twice in each interval of time comprised between the consecutive returns of the moon to the same meridian. The mean interval of these returns is $1^d\ 0^h\ 50'\ 28'',3$; consequently the mean interval between two following periods of high water is $12^h\ 25'\ 14'',3$. So that the retardation in the time of high water, from one day to another, is $50'\ 28''$ in its mean state: and it is affected by all those causes which influence the moon's motion.

This retardation varies with the phases of the moon. It is at its minimum towards the syzigies when the tides are at their maximum, and it is then only $38'\ 57'',1$. But, when the tides are at their minimum, or towards the quadratures, it is then the greatest possible; and amounts to $1^h\ 14'\ 58'',8$.

The variation in the distances of the sun and moon from the earth (and particularly the moon) has an influence also on this retardation. Each minute in the increase or diminution of the apparent diameter of the moon augments or diminishes this retardation $3'\ 42'',9$ towards the syzigies; but towards the quadratures the effect is three times less.

The daily retardation of the tides varies likewise with the declination of the sun and moon. In the syzigies, at the time of the solstices, it is about $2'\ 13'',9$ greater than in its mean state; and it is diminished in the same proportion, at the time of the equinoxes. On the contrary, in the quadratures, at the time of the equinoxes, it exceeds its mean state by $7'\ 49'',2$; and is in a similar manner diminished by this quantity, at the time of the solstices.

The height of the tides is also considerably influenced by all those causes which have been just mentioned; and depends on the phases

and position of the moon in her orbit. It is greatest when the moon is in the syzigies; and is diminished in the quadratures. The distance likewise of the sun and moon from the earth, as well as their declination, has a material effect upon the height of the tides.

But the state of the tides is so modified by the nature and position of the coasts, the depth of the channel, the operation of the winds, and by other causes, that the above laws will not always be found to correspond with the actual state of the tides, particularly near the coast, or in rivers. It will however be found, from the mean of a number of observations, that the inequalities in the heights and in the intervals of the tides have various periods. Some are of half a day and a day; others are of half a month and a month; whilst others again are of half a year and a year: and some are the same as the times of the revolutions of the lunar nodes and apsides.

The action of the moon upon the waters of the ocean is triple that of the sun.

Mars.

Mars is easily known in the heavens by his red and fiery appearance. He performs his sidereal revolution in $686^{d}\ 23^{h}\ 30'\ 39'',0$ or in 1·881 Julian years: and his mean synodical revolution in about 780 days, or in about 2·135 years.

His mean distance from the sun is 1·524; that of the earth being considered as unity. This makes his mean distance above 142 millions of miles.

The eccentricity of his orbit is ·093: half the major axis being considered as unity.

His mean longitude, at the commencement of the present century, was in $2^{s}\ 4^{\circ}\ 7'\ 2'',3$.

The longitude of his perihelion was, at the same time, in $11^{s}\ 2^{\circ}\ 24'\ 23'',9$: but the line of the apsides has an apparent motion, according to the order of the signs, of $1'\ 5'',9$ in a year, or $1^{\circ}\ 49'\ 52'',4$ in a century.

His orbit is inclined to the plane of the ecliptic in an angle of $1^{\circ}\ 51'\ 3'',5$: which angle decreases about $1'',4$ in a century.

His orbit at the commencement of the present century crossed the ecliptic in $1^{s}\ 18^{\circ}\ 1'\ 28'',0$: but the place of the nodes has an apparent motion in longitude, according to the order of the signs, of $26'',8$ in a year, or $44'\ 41'',5$ in a century.

The rotation on his axis is performed in $1^{d}\ 0^{h}\ 39'\ 21'',3$: and his axis is inclined to the ecliptic in an angle of $59^{\circ}\ 41'\ 49'',2$.

[His mean diameter is equal to 4398 miles: consequently he is rather more than half the size of our earth.]

His mass, compared with that of the sun considered as unity, is $\frac{1}{2546320}$.

[The proportion of light and heat, received by him from the sun, is ·43: that received by the earth being considered as unity.]

He has a very dense but moderate atmosphere: and he is not accompanied by any satellite.

As viewed from the earth, the motion of Mars appears sometimes retrograde. The mean arc which he describes in this case is $16^{\circ}\ 12'$: and its mean duration is about 73 days. This retrogradation commences, or finishes, when the planet is not more than $136^{\circ}\ 48'$ from the sun.

Mars changes his phases somewhat in the same manner as the moon does from her first to her third quarter, according to his various positions with respect to the earth and the sun: but, he never becomes cornicular, as the moon does when near her conjunctions. His mean apparent diameter is $9'',7$: which augments in proportion as the planet approaches its opposition, when it is equal to $29'',2$.

His parallax is nearly double that of the sun.

Jupiter.

Jupiter is, next to Venus, the most brilliant of all the planets: whom he sometimes however surpasses in brightness. He performs his sidereal revolution in $4332^{d}\ 14^{h}\ 18'\ 41'',0$; or in 11·862 Julian years. But this period is subject to some inequalities. He performs his mean synodical revolution in about 399 days.

His mean distance from the sun is 5·203; that of the earth being considered as unity. This makes his mean distance above 485 millions of miles.

The eccentricity of his orbit is ·0482; half the major axis being considered as unity.

His mean longitude at the commencement of the present century was in $3^{s}\ 22^{\circ}\ 0'\ 36'',1$.

The longitude of his perihelion was, at the same time, in $0^{s}\ 11^{\circ}\ 8'\ 35'',1$: but the line of the apsides has an apparent motion, according to the order of the signs, of $56'',7$ in a year, or $1^{\circ}34'33'',8$ in a century.

His orbit is inclined to the plane of the ecliptic in an angle of 1° 18′ 51″,5: which is observed to decrease nearly 22″,6 in a century.

His orbit, at the commencement of the present century, crossed the ecliptic in 3^s 8° 25′ 34″,2. But the place of the nodes has an apparent motion in longitude, according to the order of the signs, of 34″,3 in a year, or 57′ 12″,4 in a century.

The rotation on his axis is performed in 9^h 55′ 49″,7: and his axis forms an angle of 86° 54′ 30″,0 with the plane of the ecliptic.

[His mean diameter is equal to 91522 miles: consequently he is about $11\frac{1}{2}$ times as large as our earth.] The axis of his poles is to his equatorial diameter a ·9287 to 1, or as 13 to 14.

His mass, compared with that of the sun considered as unity, is $\frac{1}{1067 \cdot 09}$: but his density is ·909501.

[The proportion of light and heat, received from the sun, is ·037: that received by the earth being considered as unity.]

He is surrounded by faint substances called zones or belts; which are supposed to be parts of his atmosphere. And he is accompanied by four satellites.

A body, which weighs one pound at the equatorial surface of the earth, would, if removed to the surface of Jupiter, weigh 2·281 pounds.

As seen from the earth, the motion of Jupiter appears sometimes to be retrograde. The mean arc which he describes in this case is about 9° 54′: and its mean duration is about 121 days. This retrogradation commences, or finishes, when the planet is not more distant than 115° 12′ from the sun.

His mean apparent equatorial diameter is 38″,2: it is greatest when in opposition, at which time it is equal to 47″,6.

Saturn.

Saturn performs his sidereal revolution in 10758^d 23^h 16° 34″,2; or in 29·456 Julian years. But this period is subject to some inequalities. His mean synodical revolution is performed in about 378 days.

His mean distance from the sun is 9·539; that of the earth being considered as unity. This makes his mean distance above 890 millions of miles.

The eccentricity of his orbit is ·0562; half the major axis being taken as unity.

His mean longitude, at the commencement of the present century, was in 4ˢ 15° 20′ 31″,5.

The longitude of his perihelion was, at the same time, in 2ˢ 29° 8′ 57″,9: but the line of the apsides has an apparent motion in longitude, according to the order of the signs, of 1′ 9″,5, in a year, or 1° 55′ 47″,1 in a century.

His orbit is inclined to the plane of the ecliptic in an angle of 2° 29′ 38″,1: which is observed to decrease about 15″,5 in a century.

His orbit, at the commencement of the present century, crossed the ecliptic in in 3ˢ 21° 35′ 46″,5: but the place of the nodes has an apparent motion in longitude, according to the order of the signs, of 27″,4 in a year, or 45′ 43″,5 in a century.

The rotation on his axis is performed in 10ʰ 16′ 19″,2: [and the axis is inclined in an angle of 58° 41′ to the plane of the ecliptic.]

[His mean diameter is 76068 miles: consequently he is nearly 10 times as large as our earth.] The axis of his poles is to his equatorial diameter as 11 to 12.

His mass, compared with that of the sun considered as unity, is $\frac{1}{3359,40}$ [but his density is ·08.]

[The proportion of light and heat received from the sun is ·0011; that received by the earth being considered as unity.]

Saturn is sometimes marked by zones or belts; which are probably obscurations in his atmosphere. And he is accompanied by seven satellites.

The most singular phenomenon, however, attending this planet, is the double ring with which he is surrounded.

This ring, which is very thin and broad, is inclined to the plane of the ecliptic in an angle of 31° 19′ 12″,0; and revolves from west to east, in a period of 10ʰ 29′ 16″,8, about an axis perpendicular to its plane and passing through the centre of the planet.

The breadth of the ring is nearly equal to its distance from the surface of Saturn: that is, about $\frac{1}{3}$ of the diameter of the planet.

The surface of the ring is separated in the middle by a black concentric band, which divides it into two distinct rings.

The edge of this ring, being very thin, sometimes disappears: and, as this edge will present itself to the sun twice in each revolution of the planet, is is obvious that the disappearance of the ring

will occur about once in 15 years; but under circumstances oftentimes very different.

[The intersection of the ring and the ecliptic is in $5^s\ 20°$ and $11^s\ 20°$; consequently, when Saturn is in either of those signs, his ring will be invisible to us. On the contrary, when he is in $2^s\ 20°$ or $8^s\ 20°$, we may see it to most advantage. This was the case towards the end of the year 1811. Regard, however, must be had to the position of the earth.]

As viewed from the earth, the motion of Saturn sometimes appears retrograde. The mean arc which he describes in this case is about $6°\ 18'$: and its duration is nearly 139 days. This retrogradation commences, or finishes, when the planet is distant about $108°\ 54'$ from the sun.

His mean apparent diameter is $17'',6$.

Telescopic Planets.

Uranus was discovered by Dr. Herschel, March 13, 1781, who gave it the name of the *Georgium Sidus*. It performs its sidereal revolution in $30688^d\ 17^h\ 6'\ 16'',2$; or in about 84 Julian years: and it is probably situated at the confines of the planetary system.

Its distance from the sun is upwards of 1800 millions of miles: and its apparent diameter is scarcely $3'',9$.

Its mass, compared with that of the sun considered as unity, is $\frac{1}{19504}$.

Six satellites accompany this planet; which move in orbits nearly perpendicular to the plane of the ecliptic.

The elements of the four remaining telescopic planets are not yet ascertained with sufficient precision.

Satellites.

The number of satellites in our system, at present known, is eighteen: namely, the Moon which revolves round the earth; four that belong to Jupiter, seven to Saturn, and six to Uranus. The moon is the only one visible to the naked eye.

They all move round their primary planets, as their centre, by the same laws as those primary ones move round the sun: namely,

I. The orbit of each satellite is an ellipse, of which the primary planet occupies one of the foci.

II. The areas, described about the primary planet, by the radius vector of the satellite, are proportional to the times employed in describing them.

III. The squares of the times of the revolutions of the satellites, round their respective primary planets, are to each other as the cubes of their mean distances from the primary.

Moon.

The motions of the moon are exceedingly eccentric and irregular. She performs her mean sidereal revolution in $27^d\ 7^h\ 43'\ 11'',5$. But this period is variable: and a comparison of the modern observations with the ancient proves incontestably an acceleration in her mean motion. Her mean tropical revolution is $27^d\ 7^h\ 43'\ 4'',7$; and her mean synodical revolution is $29^d\ 12^h\ 44'\ 2'',8$.

Her mean distance from the earth is 29·982175 times the diameter of the terrestrial equator; or above 237 thousand miles.

The eccentricity of her orbit is ·0548553; the mean distance from the earth being taken equal to unity. But this eccentricity is variable in each revolution.

Her mean longitude, at the commencement of the present century, was in $3^s\ 21°\ 36'\ 42'',1$.

Her velocity varies in different parts of her orbit. She is swiftest in her perigee (or point nearest the earth); and slowest when in her apogee (or point furthest from the earth). Her mean diurnal velocity is equal to $13°\ 10'\ 34'',9$, or about 13 times greater than that of the sun.

The greatest equation of her centre is $6°\ 17'\ 54'',5$.

The mean longitude of her perihelion was, at the commencement of the present century, in $8^s\ 26°\ 6'\ 5'',1$; but the line of the apsides has a motion, according to the order of the signs. The period of a sidereal revolution of the apsides is $3232^d\ 13^h\ 56'\ 16'',8$, or nearly 9 years. The period of a tropical revolution of the apsides is but $3231^d\ 11^h\ 24'\ 8'',6$. But these periods are not uniform; for they have a secular irregularity, and are retarded whilst the motion of the moon itself is accelerated. The period of an anomalistic revolution of the moon is $27^d\ 13^h\ 18'\ 37'',4$.

Her orbit is inclined to the plane of the ecliptic in an angle of $5°\ 9'$; but this inclination is variable. The greatest inequality, which sometimes extends to $8'\ 47'',1$, is proportional to the co-sine

of the angle on which the inequality in the motion of the nodes depends.

Her orbit, at the commencement of the present century, crossed the ecliptic in 0ˢ 15° 55′ 26″,3; but the place of her nodes is variable. They have a retrograde motion, and make a sidereal revolution in 6793ᵈ 10ʰ 6′ 30″,0; or in about 18·6 Julian years. This variation, however, is subject to many inequalities; of which the greatest is proportional to the sine of double the distance of the moon from the sun; and extends to 1° 37′ 45″,0 at its maximum. A synodical revolution of the nodes is performed in 346ᵈ 14ʰ 52′ 43″,6. The motion of the nodes is subject also to a secular inequality, dependent on the acceleration of the moon's mean motion.

The rotation of the moon on her axis is equal and uniform; and it is performed in the same time as the tropical revolution in her orbit, whence she always presents nearly the same face to the earth. But, as the motion of the moon in her orbit, is periodically variable, we sometimes see more of her eastern edge, and sometimes more of her western edge. This appearance is called the libration of the moon in longitude.

The axis of the moon is inclined to the plane of the ecliptic in an angle of 88° 29′ 49″. In consequence of this position of the moon, her poles alternately become visible to, and obscured from us: and this phenomenon is called her libration in latitude.

There is also another optical deception arising from the moon being seen from the surface of the earth, instead of the centre. This appearance is called her diurnal libration.

There are other inequalities in the moon's motion, arising from the action and influence of the sun. The principal of these are,

1. The evection; whose constant effect is to diminish the equation of the centre in the syzigies, and to augment it in the quadratures. If this diminution and increase were always the same, the evection would depend only on the angular distance of the moon from the sun; but its absolute value varies also with the distance of the moon from the perigee of its orbit. After a long series of observations, we are enabled to represent this inequality by supposing it equal to the sine of double the distance of the moon from the sun, minus the distance of the moon from its perigee. At its maximum, it amounts to 1° 18′ 2″,4.

2. The variation; which disappears in the syzigies and quadra-

M 2

tures, and is greatest in the octants. It is then equal to 31′ 44″,1: whence it is proportional to the sine of double the distance of the moon from the sun. Its duration is half a synodical revolution of the moon.

3. The annual equation; which follows exactly the same law as the equation of the centre of the sun, with a contrary sign. For, when the earth is in its perihelion, the orbit of the moon is enlarged by the action of the sun; and the moon therefore requires more time to perform her revolution. But, as the earth proceeds towards its aphelion, the moon's orbit contracts. Hence the period of this inequality is an anomalistic year; and, at its maximum, it amounts to 11′ 15″,9. It is subject to a secular inequality.

The figure of the moon is that of an oblate spheroid like the earth. Her mean diameter is in the proportion to that of the earth, as 5823 to 21332; or as 1 to 3·665. Whence her mean diameter will be about 2160 miles.

Her volume, compared with that of the earth, is $\frac{1}{49}$; but her mass is only $\frac{1}{68 \cdot 7}$.

The apparent diameter of the moon varies according to her distance from the earth. When nearest to us it is 33′ 31″,1; but at her greatest distance it is 29′ 21″,9. Her mean apparent diameter is 31′ 26″,5.

Her mean horizontal parallax is equal to 57′ 34″,2.

The phases of the moon are caused by the reflection of the sun's light; and depend on the relative positions of the sun, the earth, and the moon

An eclipse of the moon can take place only at the time of her opposition to the sun; and is caused by her passing through the shadow of the earth. That shadow is 3½ times longer than the distance between the moon and the earth: and its breadth, where it is traversed by the moon, is about 2$\frac{2}{3}$ times greater than the diameter of the moon. The breadth of the earth's shadow, where it is traversed by the moon, is equal to the difference between the semidiameter of the sun, and the sum of the horizontal parallaxes of the sun and moon.

[The moon cannot be eclipsed, however, if her distance from the place of her node, at the time of her opposition, exceeds 13° 21′; but, if it is within 7° 47′, there will certainly be an eclipse. The

duration of the eclipse will depend on the apparent diameter of the moon, and on the breadth of the shadow at the point where she traverses it.]

The sun cannot be eclipsed unless the moon be in conjunction; and then only when the centres of the sun and moon are in the same straight line with the eye of the spectator on the earth. In such case, if the apparent diameter of the moon be greater than that of the sun, the eclipse will be total; but, if it be less, it will be annular. Partial eclipses, however, may arise; as in the case of lunar eclipse.

[The sun cannot be totally obscured for a longer period of time than four minutes; but the moon may be hid from our view for a much longer period.]

[The number of eclipses in a year cannot be less than two, nor more than seven.]

Eclipses generally return in the same order and magnitude at the end of 223 lunations. For, in 223 mean synodical revolutions, there are $6585^d\ 7^h\ 42'\ 31'',7$; and, in $6585^d\ 18^h\ 41'\ 45'',6$ there are 19 mean synodical revolutions of the moon's nodes. Therefore, at the end of $6585^d\ 7^h\ 42'\ 31'',7$, the moon's mean longitude will be only $28'\ 32''$ behind the mean place of her nodes. In 6585 days there are 18 Julian years and 11 days, if there are four leap years in that period; but if there are five leap years, they form no more than 18 Julian years and 10 days.

The atmosphere of the moon, if it has any, must be extremely attenuated; and must be more rare than that which we can produce with our best air-pumps.

The light of the moon is 300000 times more weak than that of the sun. Its rays, collected by the aid of powerful glasses, do not produce any sensible effect on the thermometer.

The refraction of the rays of light, at the surface of our earth, must be at least 1000 times greater than the surface of the moon.

Volcanoes and mountains are discovered on her surface, by the aid of the telescope.

A body projected from the surface of the moon, with a momentum that would cause it to proceed at the rate of about 8200 feet in the first second of time, and whose direction should be in a line which at that moment passed through the centre of the earth and moon,

would not fall again to the surface of the moon, but would become a satellite to the earth. Its primitive impulse might, indeed, be such as to cause it even to precipitate to the earth. The stones, which have fallen from the air, may be accounted for in this manner

Satellites of Jupiter.

By the aid of the telescope we may discover four satellites revolving round Jupiter. The sidereal revolutions of these bodies are given in the following table: together with their mean distances from Jupiter, the semi-diameter of that planet's equator being considered as unity; and likewise their masses, compared with Jupiter considered also as unity.

Satellite.	Sidereal Revolution.		Mean Distance.	Mass.
I.	$1^d\ 18^h\ 27'\ 33'',5$	1^d 769137788148	5·812964	·0000173281
II.	3 13 13 42 ,0	3 551181017849	9·248679	·0000232355
III.	7 3 42 33 ,4	7 154552783970	14·752401	·0000884972
IV.	16 16 31 49 ,7	16 688769707084	25·946860	·0000426591

First Satellite. The inclination of the orbit of this satellite does not differ much from the plane of Jupiter's orbit. Its eccentricity is insensible.

Second Satellite. The eccentricity of the orbit of this satellite is also insensible. The inclination of its orbit, to that of its primary, is variable, as well as the position of its nodes.

Third Satellite. This satellite has a little eccentricity, and the line of its apsides has a direct but variable motion; the eccentricity itself is also subject to very sensible variations. The inclination of its orbit to that of Jupiter, and the position of its nodes, are far from being uniform.

Fourth Satellite. The eccentricity of this satellite is greater than that of any of the other three; and the line of the apsides has an annual and direct motion of $42'\ 58'',7$. The inclination of its orbit, with the plane of Jupiter's orbit, forms an angle of about $2°\ 25'\ 48''$; but this angle, although stationary about the middle of the last century, has lately begun to increase very sensibly. At the same time the motion of its nodes has begun to diminish.

The motions of the first three satellites are related to each other by a most singular analogy. For, the mean sidereal or synodical

motion of the first, added to twice that of the third, is constantly equal to three times the mean motion of the second. And, the mean sidereal or syno dicallongitude of the first, minus three times that of the second, plus twice that of the third, is always equal to two right angles.

The satellites of Jupiter are liable to be eclipsed by passing through his shadow; and, on the other hand, they are frequently seen to pass over his disk, and eclipse a portion of his surface. This happens to the first and second satellite, at every revolution; the third very rarely escapes in each revolution; but the fourth (on account of its great distance and inclination) is seldom obscured.

These eclipses are of great utility in enabling us to determine the longitude of places, by their observation; and they likewise exhibit some curious phænomena with respect to light.

From the singular analogy, above alluded to, it follows that (for a great number of years at least) the first three satellites cannot be eclipsed at the same time: for in the simultaneous eclipses of the second and third, the first will always be in conjunction with Jupiter, and *vice versâ*.

Satellites of Saturn.

Seven satellites may be seen by means of the telescope, to revolve about Saturn; the elements of which are but little known, on account of their great distance. The following Table will show the duration of their sidereal revolutions, and their mean distances in semi-diameters of Saturn.

Satellite.	Sidereal Revolution.		Mean Distance.
I.	$0^d\ 22^h\ 37'\ 30'',1$	0^d 94271	3·080
II.	1 8 53 8 ,7	1 37024	3·952
III.	1 21 18 25 ,9	1 88780	4·893
IV.	2 17 44 51 ,1	2 73948	6·268
V.	4 12 25 11 ,1	4 51749	8·754
VI.	15 22 41 13 ,9	15 94530	20·295
VII.	79 7 54 37 ,4	79 32960	59·154

The orbits of the first six satellites appear to be in the plane of Saturn's ring; whilst the seventh varies from it very sensibly.

Satellites of Uranus.

Six satellites revolve round Uranus; which, together with their primary, can be discovered only by the telescope. The following Table will show their sidereal revolutions, and mean distances in semi-diameters of the primary.

Satellite.	Sidereal Revolution.		Mean Distance.
I.	$5^d\ 21^h\ 25'\ 20'',6$	$5^d\ 8926$	13·120
II.	8 16 57 47 ,5	8 7068	17·022
III.	10 23 3 59 ,0	10 9611	19·845
IV.	13 10 56 29 ,8	13 4559	22·752
V.	38 1 48 0 ,0	38 0750	45·507
VI.	107 16 39 56 ,2	407 6944	91·008

All these satellites move in a plane which is nearly perpendicular to the plane of the planet's orbit, and contrary to the order of the signs!

[*Phil. Mag.*]

CHAP. XVII.

ON THE DISCOVERY OF THE LAW OF UNIVERSAL GRAVITATION.

Descartes was the first who endeavoured to reduce the motions of the heavenly bodies to some mechanical principle. He imagined vortices of subtle matter, in the centre of which he placed these bodies. The vortex of the sun forced the planet into motion; that of the planet, in the same manner, forced its satellite to revolve round it. The motion of comets traversing the heavens in all directions, destroyed these vortices, as they had before destroyed the solid crystalline spheres of the ancient astronomers. Thus, Descartes was no happier in his mechanical, than Ptolemy in his astronomical theory. But their labours have not been useless to science. Ptolemy has transmitted to

us, through fourteen centuries of ignorance, the few astronomical truths which the ancients had discovered. Descartes, born at a later period, and at a time when an universal curiosity was excited, which he himself had increased by substituting, in the place of ancient errors, others more seducing, and resting on the authority of his geometrical discoveries, was enabled to destroy the empire of Aristotle and Ptolemy, which might have stood the attack of a more careful philosopher; but by establishing as a principle, that we should begin by doubting of every thing, he himself warned us to examine his own system with severity, which could not long resist the new truths that were opposed to it. It was reserved for Newton to teach us the general principles of the heavenly motions. Nature not only endowed him with a profound genius, but placed his existence in a most fortunate period. Descartes had changed the face of the mathematical sciences, by the application of algebra to the theory of curves and variable functions. The geometry of infinites, of which this theory contained the germ, began to appear in various places. Wallis, Wren, and Huygens, had developed the laws of motion; the discoveries of Galileo, on falling bodies, and of *Huygens* on evolutes and centrifugal force, led to the theory of motion in curves; Kepler had determined those described by the planets, and had formed a remote conception of universal gravitation; and finally, Hook had distinctly perceived that their motion was the result of a projectile force, combined with the attractive force of the sun. The science of celestial mechanics wanted nothing more to bring it to light, but the genius of a man, who, by generalizing these discoveries, should be capable of perceiving the law of gravitation; it is this which Newton accomplished in his immortal work on the Mathematical Principles of Natural Philosophy. This philosopher, so deservedly celebrated, was born at Woolstrop, in Lincolnshire, towards the latter end of the year 1642, the year in which Galileo died. His first success in his early studies, announced his future reputation; a cursory perusal of elementary books, was sufficient to make him comprehend them; he next read the Geometry of Descartes, the Optics of Kepler, and the Arithmetic of Infinites, by Wallis, but soon aspiring to new inventions, he was, before the age of twenty-seven, in possession of his method of fluxions, and his theory of light. Anxious for repose,

and averse to literary controversy, he delayed publishing his discoveries. His friend and preceptor, Dr. Barrow, exerted himself in his favour, and obtained for him the situation of professor of mathematics in the university of Cambridge; it was during this period, that, yielding to the request of Halley, and the solicitations of the Royal Society, he published his *Principia*. The university, of which he was a member, chose him for their representative in the conventional parliament of 1688, and for that which was convened in 1701. He was knighted and appointed director of the mint by Queen Anne; he was elected president of the Royal Society in 1703, which dignity he enjoyed till his death, in 1727. During the whole of his life he obtained the most distinguished consideration, and the nation to whose glory he had so much contributed, decreed him at his death public funeral honours.

In 1666, Newton retired into the country, and, for the first time, directed his thoughts to the system of the world. The descent of heavy bodies, which appears nearly the same at the summit of the highest mountains as at the surface of the earth, suggested to him the idea, that gravity might extend to the moon, and that being combined with some motion of projection, it might cause it to describe its elliptic orbit round the earth. To verify this conjecture, it was necessary to know the law of the diminution of gravity. Newton considered, that if the moon was retained in its orbit by the gravity of the earth, the planets should also be retained in their orbits by their gravity towards the sun, and demonstrated this by the law of the areas being proportional to the times. Now it results from the relation of the squares of the times to the cubes of the greater axis of their orbits, that their centrifugal force, and consequently their tendency to the sun, diminishes inversely as the squares of the distances from this body. Newton, therefore, transferred to the earth this law of the diminution of the force of gravity, and reasoning from the experiments of falling bodies, he determined the height which the moon, abandoned to itself, would fall in a short interval of time. This height is the versed sine of the arc which it describes in the same interval; and this quantity the lunar parallax gives in parts of the radius of the earth, so that, to compare the law of gravitation with observation, it was necessary to know the magnitude of this radius; but Newton having, at that

time, an erroneus estimate of the terrestrial meridian, obtained a different result from what he expected; and suspecting that some unknown forces united themselves with the gravity of the moon, abandoned his original idea. Some years afterwards, a letter from Dr. Hook induced him to investigate the nature of the curve described by projectiles round the centre of the earth. Picard had lately finished the measure of a degree in France, and Newton found, by this measure, that the moon was retained in its orbit by the force of gravity alone, supposed to vary inversely as the square of the distance. By this law he found that bodies in their fall describe ellipses, of which the centre of the earth occupies one of their foci, and then, considering that the planetary orbits are likewise ellipses, having the sun in one of their foci, he had the satisfaction to see, that the solution which he had undertaken from curiosity, could be applied to the greatest objects in nature. He arranged the several propositions relative to the elliptic motions of planets, and Dr. Halley having induced him to publish them, he composed his grand work, the Principia, which appeared in 1687. These details, which have been transmitted to us by his friend and contemporary Dr. Pemberton, prove that this great philosopher had, so early as 1666, discovered the principal theorems on centrifugal force, which Huygens published six years afterwards, at the end of his work De Horologio Oscillatorio; for, indeed it is highly probable that the author of the method of fluxions, who seems then to have been in possession of it, should easily have discovered these theorems. Newton arrived at the law of the diminution of gravity, by the relation which subsists between the squares of the periodic times, and the cubes of the greater axes of their orbits, supposed circular. He demonstrated that this relation exists in elliptic orbits generally, and that it indicates an equal gravity of the planets towards the sun, supposing them at an equal distance from its centre. The same equality of gravity towards the principal planet, exists likewise in all the systems of satellites, and Newton verified it on terrestrial bodies by very accurate experiments.

This great geometrician, by considering this question generally, demonstrated that a projectile can move in any conic-section whatever, in consequence of a force directed towards its centre, and varying reciprocally as the square of the distances. He investigated the different properties of motion in this species of curves; he de-

termined the conditions requisite for the section to be a circle, an ellipse, a parabola, or an hyperbola, which conditions depend entirely on the velocity and primitive position of the body.

Any velocity, position, and initial direction of a body being given, Newton assigned the conic section which the body should describe, and in which it ought consequently to move, which repels the reproach which John Bernouilli applied to him of not having demonstrated, that the conic sections are the only curves which a body, solicited by a force varying reciprocally as the squares of the distance, can describe. These investigations, applied to the motion of comets, informed him that these bodies move round the sun, according to the same laws as the planets, with the difference only of their ellipses being very eccentric; and he gave the means of determining by observation, the elements of these ellipses.

He learned from the comparison of the distance and duration of the revolutions of satellites, with those of the planets, the respective densities and masses of the sun, and of planets accompanied by satellites, and the intensity of the force of gravity at their surface.

By considering that the satellites move round their planets very nearly, as if the planets were immovable, he discovered that all these bodies obey the same force of gravity towards the sun.

The equality of action and reaction, did not permit him to doubt, that the sun gravitated towards the planets, and these towards their satellites; and even that the earth is attracted by all the bodies that rest upon it. He extended this proposition afterwards by analogy, to all the celestial bodies, and established as a principle, *that all particles of matter attract each other directly as their mass, and inversely as the square of their distance.*

Arrived at this principle, Newton saw that the great phænomena of the system of the world might be deduced from it. By considering gravity at the surfaces of the celestial bodies, as the result of the attractions of all their particles, he ascertained these remarkable truths, that the attracting force of a body, or of a spherical stratum, on a point placed without it, is the same as if its mass was compressed into its centre; and that a point placed within a spherical stratum, or generally any stratum terminated by two elliptic surfaces, similar and similarly situated, is equally attracted on every side.

He proved that the motion of rotation of the earth, ought to

have flattened it in the direction of the poles, and he determined the law of the variation of the degrees and of gravity, supposing it homogeneous.

He saw that the action of the sun and moon on the terrestrial spheroid ought to produce a motion in its axis of rotation, to make the equinoxes retrograde, to elevate the waters of the ocean, and to produce in this great fluid mass the oscillations which are observed under the name of tides.

Lastly, he was convinced that the lunar irregularities were produced by the combined action of the sun and earth on this satellite. But with the exception of what concerns the elliptic motion of the planets and comets, the attraction of spherical bodies, and the intensity of gravity at the surface of the sun, and of those planets that are accompanied by satellites, all these discoveries were only sketched by Newton. His theory of the form of the planets is limited by the supposition of their homogenity; his solution of the problem of the precession of the equinoxes, though very ingenious, is, notwithstanding the apparent agreement of his result with observation, in many respects defective; in the great number of the perturbations of the celestial motions, he has only considered those of the lunar motion, of which the most considerable, the evection, has escaped his investigation. He has perfectly established the existence of the principle which he discovered, but the development of its consequences and its advantages, has been the work of the successors of this great geometer. The state of imperfection in which the infinitesmal calculus must have been in the hands of its inventor, did not permit him to resolve completely the difficult problems which the theory of the system of the world presents; and he was often obliged to give conjectures, uncertain till they have been since verified by a rigorous calculation. Notwithstanding these inevitable defects, the importance and extent of his discoveries, the great number of original and profound conceptions, which have been the germ of the most brilliant theories of the geometers of the present times, and arranged with much elegance, insures to his *Principia* a pre-eminence over all other productions of human intellect.

The case is not the same with the sciences as with literature; the last has limits which a man of genius may reach when he employs a

language brought to perfection; he is read with the same interest in all ages; and time only adds to his reputation by the vain efforts of those who try to imitate him.

The sciences, on the contrary, unbounded like nature herself, increase infinitely by the labours of successive generations the most perfect work; by raising them to a height from which they can never again descend, they give birth to new discoveries which produce in their turn new works which efface the former from which they originated. Others will present in a point of view more general and more simple, the theories described in the *Principia*, and all the truths which it has displayed; but the *Principia* will still remain an eternal monument of the profundity of that genius which has unfolded to us the greatest law of the universe.

This work and the equally original treatise by the same author on *Optics*, have still the merit of being the best models which he proposed in the sciences, and in the delicate art of making experiments and submitting them to calculation. We here see the most beautiful applications of the method which consists in tracing the principal phænomena to their causes by a succession of inductions, and afterwards of redescending from these causes, to all the details of the phænomena.

General laws are impressed in all individual cases, but they are complicated with so many extraneous circumstances, that the greatest address is often necessary to develop them. The phænomena most proper for this object must be chosen, they must be multiplied that the attendant circumstances may be varied, and that whatever they have in common may be observed.

We thus ascend successively to relations more and more extended, and we arrive at length at general laws, which are verified either by proofs or by direct experiment, if that is possible, or by examining if they satisfy all the known phænomena.

This is the most certain method by which we can be guided in the search of truth. No philosopher has adhered more faithfully to this method than Newton; it conducted him to his discoveries in analysis, and it led him to the principle of universal gravitation; and to the properties of light. Other philosophers in England, contemporaries of Newton, adopted it by his example, and it was the base of a great number of excellent works which then appeared.

The philosophers of antiquity following a contrary path, and considering themselves as at the source of every thing, imagined general causes to explain them.

Their method, which was only productive of vain systems, had not greater success in the hands of Descartes. In the time of Newton, Leibnitz, Malebranche and other philosophers, employed it with as little advantage.

At length the inutility of the hypotheses, to which it led its followers, and the progress for which the sciences are indebted to the method of inductions, has brought back all philosophers to this last process, which Bacon established with all the force of reason and eloquence, and which Newton yet more strongly recommended by his discoveries.

It is by means of synthesis that this great geometer has explained his theory of the system of the world. It appears, however, that he found the greater part of his theorems by analysis, the limits of which he has considerably extended, and to which he allows himself to have owed his general results on the quadratures of curves.

But his great predilection for synthesis, and his esteem for the geometry of the ancients, has induced him to represent his theorems, and even his method of fluxions, under a synthetic form. And it is evident by the rules and examples which he has given of these transformations in many works, how much importance he attached to it. We may regret with the geometers of his time, that he has not followed in the exposition of his discoveries, the path by which he arrived at them; and that he has suppressed the demonstration of many results, such as the equation of the solid of least resistance, preferring the pleasure of leaving it to be divined to that of enlightening his readers.

The knowledge of the method which has guided a man of genius is not less serviceable to the progress of the sciences, and even to his own glory, than his discoveries; and the principal advantage which has been derived from the famous dispute between Newton and Leibnitz, concerning the invention of the infinitesimal calculus, has been to make known the path of these two great men, in their first analytical labours.

The preference of Newton for the synthetical method, may be explained by the elegance with which he connected his theory of

curvilinear motion, with the investigations of the ancients on the conic sections, and the beautiful discoveries which Huygens had published according to this method. Geometrical synthesis has besides the property of never losing sight of its object, and of enlightening the whole path which leads from the first axioms to their last consequences, while algebraic analysis soon makes us forget the principal object, to occupy ourselves with abstract combinations, and only brings us back to it at the end. But in thus quitting the object of investigation, after having assumed what is indispensably necessary to arrive at the required result, by directing all our attention to the operations of analysis, and reserving all our forces to overcome the difficulties which present themselves, we are conducted by the universality of this method,—by the inestimable advantage of thus transferring the train of reasoning in mechanical questions,—to results often inaccessible to synthesis. The theory of the system of the world offers a great number of examples of this power of analysis which give it a degree of perfection it would never have acquired had no other path been followed than that traced by Newton. Such is the fecundity of analysis, that if we translate particular truths into this universal language, we shall find a number of new and unexpected truths arise merely from the form of expression. No language is so susceptible of the elegance which arises from the development of a long train of expressions connected with each other, and all flowing from the same fundamental idea. Analysis unites to all these advantages that of being ever able to conduct us to the most simple methods. Nothing more is requisite than to apply it in a convenient manner by a judicious choice of unknown quantities, and by giving to the results the form most easily reducible to geometrical construction, or to numerical calculation. The geometricians of the present century, convinced of its superiority, have peculiarly applied themselves to extend its domain, and enlarge its boundaries.

Geometrical considerations, however, ought not to be abandoned; they are of the greatest utility in the arts. Besides which it is curious to imagine the different results of analysis represented in space; and reciprocally, to read all the affections of lines and surfaces, and all the variations in the motions of bodies, in the equations which express them. This approximation of geometry and analysis, diffuses a new light over the sciences; the intellectual

operations of the latter, rendered perceptible by the images of the former, are more easy to comprehend, and more interesting to pursue; and when observation realizes these images, and transforms these geometrical results into laws of nature, and when both, embracing the whole universe, display to our contemplation its present and future state, the view of so sublime a spectacle, presents to us one of the most noble pleasures that have been kept in reserve for mankind.

Nearly fifty years have now passed away since the discovery of the theory of gravitation, without any remarkable addition to it. All this time has been necessary to render so great a truth generally understood, and to surmount the obstacles opposed to it by the system of vortices, and the authority of geometricians contemporary with Newton, who combatted it perhaps from vanity, but who nevertheless accelerated its progress by their labours on infinitesimal analysis.

At length astronomers have conceived the fortunate idea of applying this analysis to the celestial motions by reducing them to differential equations, which they have rigorously integrated, or by converging approximation. They have thus explained by the law of gravitation all the known phænomena of the system of the world, and have given an unhoped for precision to astronomical tables. It has been necessary, for this object, to bring to perfection at once mechanics, optics, and analysis, which principally owe their rapid improvements to their being necessary to the purposes of physical astronomy. It might be rendered yet more correct and simple, but posterity will no doubt see with gratitude that the geometers of the present century have transmitted no astronomical phenomenon of which they have not determined the cause and the law.

Justice to France requires us to observe, that if England have had the advantage of giving birth to the discovery of universal gravitation, it is principally to the French geometers, and to the patronage of the Academy of Sciences, that we are indebted for numerous developments of this discovery, and the revolution which it has produced in astronomy.

[*La Place, Système du Monde.*]

CHAP. XVIII.

OBSERVATIONS ON THE PLANET VENUS, BY DR. HERSCHEL.

THE planet Venus is an object that has long engaged my particular attention. A series of observations on it, which I began in April 1777, has been continued down to the present time. My first view, when I engaged in the pursuit, was to ascertain the diurnal rotation of this planet, which, from the contradictory accounts of Cassini and Bianchini, the former of which states it at 23 hours, while the latter makes it 24 days, appeared to remain unknown, as to its real duration: for the observations of these gentlemen, how widely different soever with regard to time, can leave no doubt but that this planet actually has a motion on its axis.

The next object was the atmosphere of Venus; of the existence of which also, after a few months observations, I could not entertain the least doubt. The investigation of the real diameter was the 3d object I had in view. To which may be added, in the last place, an attention to the construction of the planet, with regard to permanent appearances; such as might be occasioned by, or ascribed to, seas, continents, or mountains.

The result of my observations would have been communicated long ago, if I had not still flattered myself with the hopes of some better success, concerning the diurnal motion of Venus; which, on account of the density of the atmosphere of this planet, has still eluded my constant attention, as far as concerns its period and direction. Even at this present time I should hesitate to give the following extract from my journals, if it did not seem incumbent on me to examine by what accident I came to overlook mountains in this planet, which are said to be of such enormous height, as to exceed 4, 5, and even 6 times the perpendicular elevation of Cimboraço, the highest of our mountains*!

The same paper, which contains the lines I have quoted, gives us

* See Phil. Trans. for 1792, part 2, page 337.

likewise many extraordinary accounts, equally wonderful; such as hints of the various and singular properties of the atmosphere of Saturn *. A ragged margin in Venus, resembling the uneven border of the moon, as it appears to a power magnifying from 1 to 4 †. One cusp of Venus appearing pointed, and the other blunt, owing to the shadow of some mountain ‡. Flat spherical forms conspicuous on Saturn §. All which being things of which I have never taken any notice, it will not be amiss to show, by what follows, that neither want of attention, nor a deficiency of intruments, could occasion my not perceiving these mountains of more than 23 miles in height ‖; this jagged border of Venus; and these flat spherical forms on Saturn.

Indeed with regard to Saturn, I cannot hesitate a single moment to say, that had any such things as flat spherical forms existed, they could not possibly have escaped my notice, in the numberless observations with 7, 10, 20, and 40-feet reflectors, which I have so often directed to that planet. However, if the gentleman who has seen the mountains in Venus, has made observations on flat spherical forms on Saturn, it is to be regretted that he has not attended to the revolution of this planet on its axis, which could not remain an hour unknown to him when he saw these forms. Last night, May 31, 1793, for instance, I saw two small dark spots on Jupiter; I shall not call them flat spherical forms, because their flatness, as well as their sphericity, must be hypothetical; indeed these two terms seem to me to contradict each other. These were evidently removed, in less than an hour, in such a manner as to point out, very nearly, the direction and quantity of the rotation of this planet.

Before I remark on the rest of the extraordinary relations abovementioned, I will give a short extract of my observations on Venus, with such deductions as it seems to me that we are authorized to make from them. Thus,

April 17, 1777, the disk of Venus was exceedingly well defined,

* See Phil. Trans. for 1792, part 2, page 309.

† Ibidem, page 310.

‡ p. 312.

§ p. 336.

‖ The height of Chimbo-raço, according to Mr. Condamine, is 3200 French toises: and the English mile, by Mr. De Lalande, measures 830. If the mountains in Venus exceed Chambo-raço six times in perpendicular elevation, they must be more than 23 miles in height.

distinct, and bright, but no spot was visible by which I could judge of her diurnal motion. The same telescope shows the spots on Mars extremely well. 7-feet reflector.

April 26, 1777. The disk well defined, and bright, but no spot. 10-feet reflector.

In this manner Dr. H. sets down a number of similar observations; whence he infers, that Venus has a motion on an axis; and that she has an atmosphere he considers evident, from the changes he took notice of, which could not be on the solid body of the planet.

Then follow many other observations on the same, with some on the diameter of Venus. After all, Dr. H. adds, a very few evident results may be drawn from the foregoing observations.

With regard to the rotation of Venus on an axis, it appears that we may be assured of this planet's having a diurnal motion, and though the real time of it is still subject to considerable doubts, it can hardly be so slow as 24 days. Its direction, or rather the position of the axis of Venus, is involved in still greater uncertainty.

The atmosphere of Venus is probably very considerable; which appears not only from the changes that have been observed in the faint spots on its surface, but may also be inferred from the illumination of the cusps, when this planet is near its inferior conjunction; where the enlightened ends of the horns reach far beyond a semicircle. I must here take notice, that the author we have before quoted on this subject, has the merit of being the first who has pointed out this inference, but he has overlooked the penumbra arising from the diameter of the sun; which has certainly a considerable share in the effect of the extended illumination, and in his angle of 15° 19′ will amount to more than 1° 11′ 47″.6. His measures are also defective; as probably the mirror of his 7-feet reflector, which was a very excellent one, was by that time considerably tarnished, and had lost much of the light necessary to show the extent of the cusps in their full brilliancy.

I do not give the calculations I have made of the extent of the twilight of Venus, because my measures were not so satisfactory to myself as I wish them to be; nor so near the conjunction as we may hereafter obtain them; neither were they sufficiently repeated. My computations, however, when compared to those given in the paper on the atmosphere of Venus, show sufficiently that it is of much greater extent, or refractive power, than has been computed in that

paper. Those calculations indeed are so full of inaccuracies, that it would be necessary to go over them again, in order to compare them strictly with my own, for which at present there is no leisure.

I ought also to take notice here, that the same author, it seems, has taken measures of the horns of Venus by an instrument which, in his publications, he calls a projection table, and describes as his own; of which however, those who do not know its construction may have a very perfect idea, when they read the description of my lamp, disk, and periphery-micrometers, joined to what I have mentioned above, of using the disk micrometer without lamps when day-light is sufficiently strong; or even with an illumination in front, where the object is bright enough to allow of it, such as the moon, &c. I remember drawing the picture of a cottage by it, in the year 1776, which was at three or four miles distance; and going afterwards to compare the parts with the building, found them very justly delineated.

I have also many times had the honour of showing my friends the accuracy of the method of applying one eye to the telescope, and the other to the projected picture of the object in view; by desiring them to make two points, with a pin, on a card fixed up at a convenient place, where it might be viewed in my telescope; and this being done, I took the distance of these points from the picture I saw projected, in a pair of proportional compasses, one side of which was to the other as the distance of the object, divided by the distance of the image, to the magnifying power of the telescope; and giving the compasses to my friends, they generally found that the proportional ends of them exactly fitted the points they had made on the card. All which experiments are only so many different ways of using the lamp-micrometer.

As to the mountains in Venus, I may venture to say that no eye, which is not considerably better than mine, or assisted by much better instruments, will ever get a sight of them; though from the analogy that obtains between the only two planetary globes we can compare, (the moon and the earth) there is little doubt but that this planet also has inequalities on its surface, which may be, for what we can say to the contrary, very considerable.

The real diameter of Venus, I should think, may be inferred with great confidence, from the measures I took with the twenty-feet reflector, in the morning of the 24th of November, 1791; which,

when reduced to the mean distance of the earth, give 18″,79 for the apparent diameter of this planet. This result is rather remarkable, as it seems to prove that Venus is a little larger than the earth, instead of being a little less as has been supposed; yet, on the nicest scrutiny, I cannot find fault with the measures. The planet was put between the two wires of the micrometer, which were outward tangents; and they were, after each measure, shut so as to meet with the same edge, and in the same place where the planet was measured. In this situation the proper deduction, for not being central measures, was pointed out by the index plate. The transits of the 25th were corrected for a small concavity of the wires, which being pretty thick and stubborn, were not strained sufficiently to make them quite straight, the amount of which was also ascertained by an examination of the division where the wires closed at the ends, and where they closed in the centre. The zero was, with equal precaution, referred to a point at an equal distance from the contact of the wires on each side; for they are at liberty to pass over each other, without occasioning any derangement. The shake, or play, of the screw is less than three-tenths of a division. The two planets, however, are so nearly of an equal size, that it would be necessary to repeat our measures of the diameter of Venus, in the most favourable circumstances, and with micrometers adjusted to the utmost degree of precision, to decide with perfect confidence that she is, as appears most likely, larger than the earth.

The remarkable phenomenon of the bright margin of Venus, I find, has not been noticed by the author we have referred to; on the contrary, it is said, "this light appears strongest at the outward limb, from whence it decreases gradually, and in a regular progression, towards the interior edge or terminator." But the luminous border, as I have described it, in the observations of the 9th, 16th, 20th, and 22d of April, does not in the least agree with the above representation. With regard to the cause of this appearance, I believe that I may venture to ascribe it to the atmosphere of Venus, which, like our own, is probably replete with matter that reflects and refracts light copiously in all directions. Therefore on the border, where we have an oblique view of it, there will of consequence be an increase of this luminous appearance. I suppose the bright belts, and polar regions of Jupiter, for instance, which have a greater light than the faint streaks, or yellow belts, on that planet, to be the

parts where its atmosphere is most filled with clouds, while the latter are probably those regions which are free from them, and admit the sun to shine on the planet; by which means we have the reflection of the real surface, which I take to be generally less luminous. If this conjecture be well founded, we see the reason why spots on Venus are so seldom to be perceived. For, this planet having a dense atmosphere, its real surface will commonly be enveloped by it, so as not to present us with any variety of appearances. This also points out the reason why the spots, when any such there are, appear generally of a darker colour than the rest of the body.

[*Phil. Trans. Abridged*, 1793.]

CHAP. XIX.

AN ACCOUNT OF THREE VOLCANOES IN THE MOON, BY THE SAME.

It will be necessary to say a few words by way of introduction to the account I have to give of some appearances upon the moon. The phænomena of nature, especially those that fall under the inspection of the astronomer, are to be viewed, not only with the usual attention to facts as they occur, but with the eye of reason and experience. In this we are however not allowed to depart from plain appearances; though their origin and signification should be indicated by the most characterising features. Thus, when we see, on the surface of the moon, a great number of elevations, from half a mile to a mile and a half in height, we are strictly entitled to call them mountains; but, when we attend to their particular shape, in which many of them resemble the craters of our volcanoes, and thence argue, that they owe their origin to the same cause which has modelled many of these, we may be said to see by analogy, or with the eye of reason. Now, in this latter case, though it may be convenient, in speaking of phænomena, to use expressions that can only be justified by reasoning upon the facts themselves, it will certainly be the safest way not to neglect a full description of them, that it may appear to

others how far we have been authorised to use the mental eye. This being premised, I may safely proceed to give my observations.

April 19, 1787, 10^h 36′ sidereal time.

I perceive three volcanoes in different places of the dark part of the new moon. Two of them are either already nearly extinct, or otherwise in a state of going to break out; which perhaps may be decided next lunation. The third shews an actual eruption of fire, or luminous matter. I measured the distance of the crater from the northern limb of the moon, and found it 3′ 57″,3. Its light is much brighter than the nucleus of the comet which M. Mechain discovered at Paris the 10th of this month.

April 20, 1787, 10^h 2′ sidereal time.

The volcano burns with greater violence than last night. I believe its diameter cannot be less than 3″, by comparing it with that of the Georgian planet; as Jupiter was near at hand, I turned the telescope to his third satellite, and estimated the diameter of the burning part of the volcano to be equal to at least twice that of the satellite. Hence we may compute that the shining or burning matter must be above three miles in diameter. It is of an irregular round figure, and very sharply defined on the edges. The other two volcanoes are much farther towards the centre of the moon, and resemble large, pretty faint nebulæ, that are gradually much brighter in the middle; but no well defined luminous spot can be discerned in them. These three spots are plainly to be distinguished from the rest of the marks upon the moon; for the reflection of the sun's rays from the earth is, in its present situation, sufficiently bright, with a ten-feet reflector, to show the moon's spots, even the darkest of them; nor did I perceive any similar phænomena last lunation, though I then viewed the same places with the same instrument.

The appearance of what I have called the actual fire or eruption of a volcano, exactly resembled a small piece of burning charcoal, when it is covered by a very thin coat of white ashes, which frequently adhere to it when it has been some time ignited; and it had a degree of brightness, about as strong as that with which such a coal would be seen to glow in faint day-light.

All the adjacent parts of the volcanic mountain seemed to be faintly illuminated by the eruption, and were gradually more obscure as they lay at a greater distance from the crater.

This eruption resembled much that which I saw on the 4th of May, in the year 1783; an account of which, with many remarkable particulars relating to volcanic mountains in the moon, I shall take an early opportunity of communicating to this Society. It differed, however, considerably in magnitude and brightness; for the volcano of the year 1783, though much brighter than that which is now burning, was not nearly so large in the dimensions of its eruption; the former seen in the telescope resembled a star of the 4th magnitude as it appears to the natural eye: this, on the contrary, shows a visible disk of luminous matter, very different from the sparkling brightness of star-light.

[*Phil. Trans.* 1787.]

CHAP. XX.

OF THE TWINKLING OF THE FIXED STARS, BY MR. MICHELL.

HAVING never yet seen any solution of the twinkling of the fixed stars, with which I could rest satisfied *, I shall offer the following, which may not perhaps be found an inadequate cause of that appearance; at least it has undoubtedly some share in producing it, especially in the smaller stars.

It is not, I think, unreasonable to suppose, that a single particle of light is sufficient to make a sensible impression upon the organs of sight. Upon this supposition, a very few particles of light, arriving at the eye in a second of time, will be sufficient to make an object visible, perhaps not more than three or four; for though the impression may be considered as momentary, yet the perception, occa-

* Some astronomers have lately adopted, as a solution of this appearance, the extreme minuteness of the apparent diameters of the fixed stars, which, they suppose, must, in consequence of this, be intercepted by every little mote that floats in the air; but, that an object should be able to intercept a star from us, it must be large enough to exceed the apparent diameter of the star by the diameter of the pupil of the eye; so that, if the star were a mathematical point, it must still be equal in size to the pupil of the eye.

sioned by it, is of a much longer duration: this sufficiently appears from the well-known experiment of a lighted body whirled round in a circle, which needs not make many revolutions in a second, to appear as one continued ring of fire. Hence then it is not improbable, that the number of the particles of light, which enter the eye in a second of time even from Sirius himself, may not exceed three or four thousand; and from stars of the second magnitude, they may therefore probably not much exceed an hundred. Now the apparent increase and diminution of the light, which we observe in the twinkling of the stars, seems to be repeated at not very unequal intervals, perhaps about four or five times in a second: why may we not then suppose, that the inequalities, which will naturally arise from the chance of the rays coming sometimes a little denser and sometimes a little rarer, in so small a number of them as must fall upon the eye in the fourth or fifth part of a second, may be sufficient to account for this appearance? An addition of two or three particles of light, or perhaps of a single one upon twenty, especially if there should be an equal deficiency out of the next twenty, would I suppose be very sensible; this seems at least probable from the very great difference in the appearance of stars, whose light is much less different than, I imagine, people are in general aware of; the light of the middle-most star in the tail of the great Bear does not, I think, exceed the light of the very small star next to it, in a greater proportion than that of about sixteen or twenty to one; and Monsieur Bouger tells us, in his Traité d'Optique before-mentioned, that he finds a difference in the light of objects of one part in sixty-six sufficiently distinguishable.

It will perhaps be objected, that the rays coming from Sirius are too numerous to admit of a sufficient inequality, arising from the common effect of chance, so frequently as would be necessary to produce this effect, whatever might happen in respect to the smaller stars; but till we know what inequality is necessary to produce this effect, we can only guess at it either one way or the other; there is however another circumstance, that seems to concur in the twinkling of the stars, besides their brightness, and this is a change of colour. Now the red and blue rays being very much fewer, I apprehend, than those of the intermediate colours, and therefore much more liable to inequality from the common effect of chance, may help very much to account for this phenomenon, a small excess

or defect in either of these making a very sensible difference in the colour.

It will now naturally be asked, why the frequency of the changes of brightness should not be often much greater, as well as sometimes less, than that abovementioned, and why the interval of the fourth or fifth, or some such part, should be pitched upon, rather than the fortieth or fiftieth part of a second, or than a whole second, &c. for, according to the length or shortness of the time assumed, the changes that will naturally occur, from the effect of chance, will be smaller or greater in proportion to each other. The answer to this question will, I think, tend to render the above solution more probable, as well as to throw a good deal of light upon the whole subject. The lengths of the times then between the changes of brightness, if I am not mistaken, depend upon the duration of the perception before-mentioned, occasioned by the impression of the light upon the eye, than which they seem to be neither much longer nor shorter. Whatever inequalities fall within a much shorter time than the continuance of this perception, will necessarily be blended together, and have no effect, but as they compose a part of the whole mass; but those inequalities, which fall in such a manner as that they may be assigned to intervals nearly equal to, or something greater than the continuance of this perception, will be so divided by the imagination, which will naturally follow, and pick them out as they arise.—*Phil. Trans.* 1767.

N. B. The light of the stars appears to the naked eye to be generally white, being too faint to excite the idea of a particular colour; but when it is concentrated by Dr. Herschel's large speculums, it becomes in various stars of various hues; and indeed to the naked eye some of the stars appear a little redder and others a little bluer. The cause of the twinkling of the stars does not, after all, appear to be fully ascertained: it is referred by other philosophers, and with some probability, to changes which are perpetually taking place in the atmosphere, and which affect its refractive density. It is said that in some climates where the air is remarkably serene, the stars have scarcely any appearance of twinkling.—*Editor.*

CHAP. XXI.

ON TWILIGHT.

For the phænomena of twilight, we are principally indebted to the light reflected by the atmosphere; when the sun is at a certain distance only below the horizon, he shines on some part of the air immediately visible to us, which affords us a portion of reflected light. The distance at which this may happen has been variously estimated, and it is perhaps actually different in different climates, being a little greater in countries near the poles than in those which are nearer the equator; there is also sometimes a secondary twilight, when the parts of the atmosphere, which reflect a faint light on the earth, are themselves indebted for this light to an earlier reflection. Some have assigned 18° as the limit of twilight, and on this supposition, allowing for refraction, the atmosphere must be capable of reflecting sensible light at the height of about 40 miles. Mr. Lambert, on the contrary, makes the limit only about 6½°. The duration of twilight is greater or less as the sun moves more or less obliquely with respect to the horizon; it is, therefore, shortest near the time of the equinoxes, since the equinoctial intersects the horizon less obliquely than any lesser circle parallel to it.—*Young's Nat. Phil.* Vol. I. p. 26.

The limit of visible twilight is when the sun is 6 degrees below the horizon. In order to find the time when the twilight is shortest, as Rad : Sin. Lat. : : S. 6° 23'. S. Sun's declination, south. Lambert Photometria, sect. 987. Schroter asserts that Venus has a twilight of more than 4°.—*Ueber die Venus,* 4to. Enfurt, 1798.

CHAP. XXII.

GENERAL ASTRONOMICAL REMARKS.

Fixed Stars.

It is impossible to determine exactly the distance of any of the fixed stars from the earth; yet we are nevertheless able to draw some conclusions that may tend to illustrate their prodigious remoteness.

1. The diameter of the earth's annual orbit, which contains at least 160 millions of miles, is but a point in comparison of the distance from the nearest star, which is supposed to be Sirius or the Dog-star. At least this star must be upwards of 6000 times more remote than the sun: for if a star should appear through a telescope half a minute broad, which is a pretty sensible magnitude, the true apparent diameter would not exceed 18° 3 minutes, which is less than the six thousandth part of the apparent diameter of the sun; and consequently the sun's distance cannot be one six thousandth part of the star's distance from the earth.

2. Could we advance towards the stars ninety-nine parts out of a hundred of the entire, and have only one part remaining, the stars would appear scarcely larger to us than they do at present; for they would show no otherwise than they do through a telescope which magnifies a hundred fold.

3. Nine parts at least in ten of the space between us and the fixed stars, can receive no greater light from the sun, or any of the stars, than that which the earth has from any of the stars in a clear night.

4. Light takes up more time in travelling from the nearest star to the earth, than our sailors in making a West India voyage, which is ordinarily performed in six weeks. Sound would not reach us from the same distance in fifty thousand years; nor a cannon-ball in a much less time: which is easily computed by allowing, according to Sir Isaac Newton, ten minutes for the journey of light from the sun

to the earth; and that sound travels at the rate of about thirteen hundred feet in a second.—Miscellanea Curiosa, Vol. I.

Flamstead, Phil. Trans. 1701, conjectures that he had found an annual paralax of 40″ or 45″; the polar distance being greatest in June. Cassini, A. P. 1717, makes the apparent diameter of Sirius several seconds; this however is denied by Halley, Phil. Trans. 1720.

Supposing Saturn to reflect one-seventh of the light that falls on him, and to be equal in brightness to a star as large as the sun, the distance of the star will be 425100 times as great as that of the sun, and its apparent diameter 0‴ 16″″. Hence we may assume the distance 500000.—Lambert. Photometria.

Michell observes, that a star of 500 times the diameter of the sun ought to recall the particles of light from an infinite distance, and thinks that a sensible effect might be produced by a star 22 times as large in diameter as the sun: the attraction of the sun ought to retard it $\frac{1}{494000}$ in an infinite distance. The light of a star of the sixth magnitude is to that of the sun as one to a hundred billions.—Phil. Trans. 1784.

Some stars, if as remote from each other as Sirius is from the sun, should be 42000 times as far off as Sirius. At this distance Sirius would be scarcely visible.—A cluster of 5000 stars, scarcely visible as a mass by the forty-feet telescope, must be above eleven millions of millions of millions of miles off.—Herschel, Phil. Trans. 1795. 1800.

Barker produces five authorities to show that Sirius was formerly reddish, and even redder than Mars, and proves that it is now white. —Phil. Trans. 1760.

Garcin observes, that at Bender Abassi in Asia, where the air is very pure and dry, the stars have a light absolutely fixed and free from twinkling. A. P. 1743.—Young Nat. Ph. II. 991.

Humboldt, by means of diaphragms, in Herschel's manner, has given the following as the comparative brightness of various stars. Sirius 1, Canopus 98, *Centauri 96, Achernar 94, α Indi 50, β 47, α Toucan 70, α Phœnicia 65, α Pavonis 78, α Gruis 81, β 75, γ 58.

Euler makes the light of the sun equal to that of 6560 candles at 1 foot distance, that of the moon to a candle at 7½ feet, of Venus to a candle at 421 feet, and of Jupiter to a candle at 1620 feet:

partly from Bouguer's experiments. Hence the sun would appear like Jupiter, if removed to 131000 times his present distance.—Mem. Berl. Acad. 1759.

Milky Way.

Lambert regards the Milky way as the elliptic of the fixed stars: he thinks the greater stars belong to the solar nebula, and that the other nebulæ are confused together in the milky way.—Photometria, § 1139.

Herschel conjectures that the milky way is the projection of our nebula, and that the sun has a motion towards its node near Cepheus and Cassiopeia, 1784. In a circle of 15′ diameter, 588 stars were counted: if these were at equal distances in a cone, the length of the cone must have been 497 times their distance. From calculations of this kind a figure of the nebula is drawn, showing a section passing through its poles at right angles to the line of the nodes. The right ascension of the pole is 186°, its polar distance 58°; 1785. —Phil. Trans. 1784—1802. Young's Nat. Phil. II.

In 1795 Dr. Herschel found 600 stars in a circle of 15′ in diameter. Phil, Trans. 1795. He traced out a variety of double stars, which he at length followed up to the number of fifty. Cassini verified this discovery of Herschel's, but differs a little as to the colour of these stars, and enquires whether they may not be satellites. A. P. 1784.—Michell, in like manner, conjectures that some stars may move round others.—Phil. Trans. 1784.

Sun.

The spots on the sun, many of which are as large, and some five or six times as large as the diameter as the earth, were first discovered by Fabricius of Wirtemberg in 1611; but their nature has been a source of perpetual controversy. Derham regarded them as clouds of volcanoes, afterwards becoming saculæ. Crabtrie, as early as 1640, described them as exhalations like clouds. Lalande, and various others, believed them to be mountains; Wilson, in opposition to Lalande, asserted them to be excavations. Herschel, Phil. Trans. 1795, represents the sun as an opaque body, probably inhabited, covered with an atmosphere in which clouds of a luminous matter are floating, and the spots as interruptions of these clouds. He believes them to exist in two strata, of which the upper only is

luminous, and the under stratum an interposition to protect the body of the sun from the luminous heat. . .

In Phil. Trans. 1801, Dr. Herschel endeavours to show that the variation in the heat of different years is owing to the more or less copious supply of fuel in the sun, and that it is this fuel that constitutes his spots

The motion of the sun, accompanied by the whole solar system, has also been maintained and doubted of. Mayer suggested that it takes place towards the corona borealis. Prevost adopted the same idea. Lichtenberg was sceptical—Herschel, id. p. 332.

Planets.

There is a material difference in the calculation of different philosophers as to the surface and temperature both of the primary and secondary planets that belong to the solar system. Thus in Chapter XVI. Mr. Baily, in his synopsis of La Place's Exposition, has calculated the proportion of light and heat existing in Mercury at rather more than six times and a half the mean light and heat of the earth; the light and heat of Venus at nearly double that of the earth; those of Mars something less than half those of the earth; those of Jupiter more than a third. Dr. Young, on the contrary, has estimated these powers prodigiously higher for Mercury and Venus, and considerably lower for Mars, Jupiter, and Saturn. His words are as follows.

"Of Mercury we know little except the length of his year, which is shorter than three of our months. Supposing all our heat to come from the sun, it is probable that the mean heat on Mercury is above that of boiling quicksilver; and it is scarcely possible that there should be any point about his poles where water would not boil. The sun's diameter would appear, if viewed from Mercury, more than twice as great as to us on the earth.

"Venus must have a climate far more temperate than Mercury, yet much too torrid for the existence of animals or vegetables, except in some circumpolar parts; her magnitude and diurnal rotation differ but little from those of the earth, and her year is only one third shorter; so that her seasons, and her day and night, must greatly resemble ours. The earth, when in opposition to the sun, must be about four times as bright as Venus ever appears to us, and must, therefore, always cast a shadow; it must be frequently, and

perhaps generally, visible in the day; and together with the moon must exhibit a very interesting object. The atmosphere of Venus is supposed to be nearly like our own, or somewhat more rare.

"The climate of Mars is as much colder than ours, as that of Venus is warmer; in other respects there is no very striking difference: the inclination of his axis to his ecliptic being nearly the same as that of the earth's axis, the changes of seasons must be nearly like our own. Dr. Herschel has observed a constant appearance of two bright spots or circles near the poles of Mars, which he attributes to the ice and snow perpetually surrounding them. It is not, however, probable that water could remain fluid in any part of Mars, and even quicksilver and alcohol would, perhaps, be frozen in his temperate climates. It is pretty certain that Mars has an atmosphere, and his dark spots seem to be occasioned by clouds: this atmosphere may, perhaps, also be the cause of the ruddy hue of his light.

"It appears to be doubtful, whether either of the three little planets newly discovered can be sufficiently solid, to give a firm footing to any material beings: we should probably weigh only a few pounds each if transported there. According to Dr. Herchel's opinion, neither Ceres nor Pallas is much larger than a good Scotch estate, although they must, sometimes, appear to each other as planets of a most respectable size. The light reflected from Ceres is of a more ruddy hue than that of Pallas; both of these planets are attended by more or less of a nebulosity, proceeding, perhaps, from copious atmospheres; and in this respect, as well as in the great inclination of their orbits, they appear to have some affinity to comets. It is tolerably certain that neither of them is 200 miles in diameter; and Juno is also probably about the same size.

"It is obvious that the most striking features of the heavens, when contemplated from Jupiter, would be the diversified positions and combinations of his satellites: their light must be faint, but yet of service; and to a traveller on the surface of this vast globe they must afford useful information, as well with respect to time as to place. Our little earth must probably be always invisible to a spectator situated on Jupiter, on account of its apparent proximity to the sun, in the same manner as a planet at half the distance of Mercury would be invisible to us. The year of Jupiter must contain nearly ten thousand of his days, and that of Saturn almost thirty thousand

Saturnian days. Besides the vicissitudes of the seven satellites revolving round Saturn, his ring must afford, in different parts of his surface, very diversified appearances of magnificent luminous arches, stretched across the heavens, especially in that hemisphere which is on the same side of the ring with the sun.

"From the Georgian planet the sun must be seen but as a little star, not one hundred and fiftieth part as bright as he appears to us. The axis of this planet being probably near to the plane of its ecliptic, it must be directed twice in the year towards the sun, and the limit of illumination must approach to the equator, so that almost every place on his surface must sometimes remain, for a great number of diurnal revolutions, in light and in darkness; the most moderate climates having one night, in their long year, equal in duration at least to several of our years: and it must be confessed that this planet would afford but a comfortless habitation to those accustomed to our summer sunshine, even if it were possible to colonize it."—Young's Nat. Phil. Vol. I.

In this difference of estimation we incline to that of Mr. Bailey. So in Chapter XVIII. we have already observed that Dr. Herschel has disproved those enormous mountains on the surface of Venus, which Schröter persuaded himself he had detected. Some astronomers have occasionally supposed that they have discovered a satellite attendant upon Venus; for an account of which the reader may turn to Mr. Short's paper, Phil. Trans. 1741, and Bode's Jahrbuch, 1777 and 1778.

In like manner Schröter calculated the moon to possess mountains four thousand toises, or nearly five miles high; and to have a twilight of such a nature as to indicate an atmosphere of three hundred toises high. Phil. Trans. 1792. Schröter. Phil. Mag. XV. Dr. Herschel, on the contrary, as we have already noticed in Chapter XIX. makes the loftiest mountains in the moon only a mile and three quarters high, and found few or no signs of a lunar atmosphere in an eclipse. The question of an atmosphere, however, is still in an unsettled state, though it is now uniformly admitted, that if the moon possess one at all, it is of an extremely attenuated nature.

Riccioli however calculated the height of the lunar mountains to be far superior to those of Schröter, and was opposed in his day by Hevelius, as Schröter has been by Herschel. These astronomers affected to divide the lunar mountains into regular orders, and to

distinguish them by separate names, in the same manner as geographers distinguish the mountains of our own globe. Derham has given a good account of their different conjectures upon these subjects in the following passage.

"By Riccioli's measures the height of what he calls Mount Sinai, or St. Katharine's Hill, is 9 Bononian miles, and that of Xaverius twelve; but according to his corrections, the former is but $8\frac{14}{15}$ miles, the latter $11\frac{1}{2}$. Which at the rate of 6020 English feet in a Bononian mile, is about 13 and 9 English miles; an height so great, considering how much the moon is less than the earth, that I cannot but think that diligent person was mistaken in his measures, and that the computations of Hevelius are much the best: who, as he was as able as any man, and made more accurate and diligent observations of the moon's face than most men ever did, so was more likely to come nearest the truth. And by his reckoning, the highest hills in the moon are but about $\frac{3}{4}$ of a German mile, and some of them but $\frac{7}{16}$ths, and some not above an Italian mile. And considering the bulk of the moon to that of the earth, these are great eminences for the moon.

"And as the lunar mountains are of prodigious heights, so many of them are of great extent. Hevelius reckons the lunar Taurus to reach to 170 German miles; Mount Sepher 150; and the lunar Apennine above 100 German miles.

"The way how to measure the height of the mountains of the moon is not difficult, nor uncertain; which is, by observing the distance between the distant golden spots, at their first appearance (which are the tops of hills) and the enlightened part of the moon. Which distance may be computed by miles, or any other equal parts, into which we can imagine the moon's diameter divided. Hevel. Selenogr. ch. 8; Galilæi Nunc. Sider. p. 14; Riccioli Almagest. L. 4. c. 8. Schol.

"On the edge of the moon which is next the sun, I could never perceive with my best glasses any the least sign of a mountain, but all to be exactly level and smooth. Only indeed there are some certain transient roughnesses and unevennesses on the limb caused by vapours, especially when the moon is near the horizon, and in windy and some other weather. At which times the motion of the air and vapours makes a pretty crispation and rolling like waves on the moon's limb, which have the appearance of moving mountains

and vallies. But on the opposite side, if the least portion of the darkened part of the moon extends beyond the enlightened part, mountains may very manifestly be discerned, exactly resembling ours on the earth. A few hours before and after the full, I have with pleasure seen the appearance of considerable mountains and bays.

"These alone I conceive are the mountains which the excellent Hevelius speaks of in several places of his Selenography, particularly in his answer to Bettinus, and other peripatetics, in ch. 6, p. 143, who denied that mountains could be in the moon, as well as many other things discovered now by the telescope."

There has been the same doubt respecting the moon's possession of seas and rivers; the spots, pits or cavities observable on her face, having in many instances been regarded as seas from a very early period. Thus Plutarch, in his book *De Facie* in Orbe Lunæ, at the beginning, cites it as Clearchus's opinion, 'Εικονας εποπτεικας ειναι και ειδωλα της μεγαλης Θαλασσης, i. e. "That what is called the face of the moon, are the images and appearances of a great sea in the moon." And about the middle of that tract, Το δε φαινομενον τυτι προσωπον. i. e. "As to that face which appears in the moon: as our earth hath certain large bays: so we conceive the moon is overspread with large hollows and ruptures, containing water, or a thick air, into which the sun-beams are not able to enter, whence no reflection is produced by them."

One of the best abridged descriptions of the general character of the moon which we have hitherto met with, is the following of Dr. Young.

"The moon performs a complete sidereal revolution in 27 days 7¾ hours, and a synodical revolution, during which she returns to the same position with respect to the earth and sun, in 29 days 12¾ hours; a period which constitutes a lunation, or a lunar month. Her orbit is inclined to the ecliptic in an angle of a little more than five degrees, but this inclination is liable to great variations: the place of its nodes is also continually changing, their motion being sometimes retrograde, and sometimes direct, but on the whole the retrograde motion prevails. The form of the moon's orbit is irregularly elliptic, and the velocity of its motion deviates considerably from the Keplerian law of the description of equal areas in equal times; the apsides, or the extremities of the greater axis of the ellipsis, which are called the apogee and perigee, have on the whole a direct

motion. From a comparison of modern observations with the most ancient, the mean motion of the moon is found to be somewhat accelerated.

"The moon revolves on her own axis with a very equable motion, and the period of her rotation is precisely equal to the mean period of her revolution round the earth; so that she always presents to us the same portion of her surface, excepting the apparent librations produced by her unequal velocities in her orbit, and by the position of her axis, which is inclined 1° 43′ to the ecliptic, and sometimes as much as 7° to her own orbit. Her distance from the earth is about 240000 miles; her diameter $\frac{3}{11}$ of that of the earth, or 2160 miles; and the weight of bodies at her surface is supposed to be about one-fifth of their weight at the surface of the earth.

"The surface of the moon presents to us, when viewed with a telescope, a great diversity of light and shade, the principal features of which are visible even to the naked eye. Many of these inequalities resemble very strongly the effects of volcanoes; several astronomers have imagined that they have seen volcanoes actually burning in the unenlightened part of the planet; and Dr. Herschel's instruments have enabled him to obtain satisfactory evidence of the truth of the conjecture. The appearance of a perforation, which Ulloa supposed that he observed near the margin of the moon's disk, in a solar eclipse, has been attributed by some to a volcano actually burning. Dr. Halley and Mr. Weidler have also observed flashes of light on the dark part of the moon, considerably resembling the effects of lightning. The height of the lunar mountains has been commonly supposed to exceed very considerably that of the mountains of the earth; but Dr. Herschel is of opinion that none of them are so much as two miles high. The names, which have been given by astronomers to various parts of the moon's surface, are of some utility in the observation of the progress of an eclipse."

"The inhabitants of the moon, if the moon be inhabited, must be capable of living with very little air, and less water. There is reason to think their atmosphere less than a mile high, and it is never clouded; so that the sun must shine without intermission for a whole fortnight on the same spot, without having his heat moderated by the interposition of air, or by the evaporation of moisture. The want of water in the moon is not, as some have supposed, the necessary

consequence of the want of an atmosphere; but it is inferred partly from the total absence of clouds, and partly from the irregular appearance of the margin of the moon, as seen in a solar eclipse; no part of it being terminated by a line sufficiently regular to allow us to suppose it the surface of a fluid. The earth must always appear to occupy nearly the same part of the sky, or rather to describe a small oval orbit round a particular point, exposing a surface 13 times as great as that of the moon appears to us. This large surface, suspended, with phases continually changing, like those of the moon, must afford, especially when viewed with a telescope, an excellent timepiece; the continents and seas coming gradually and regularly into view, and affording a variety equally pleasing and useful. To us such a timepiece would be of inestimable value, as it would afford us an easy method of discovering the longitude of a place, by comparing its motion with the solar time; but in the moon, the relative position of the earth and sun, or of the earth and stars only, would be sufficient for determining the situation of any place in sight of the earth; if, however there are no seas and no navigation, astronomical observations of this kind would be of very little utility. The assistance of the earth's phases in the measurement of time might, however, still be very useful, for many purposes, to the inhabitants of the nearer half of the moon; and probably the remoter part is much deserted, for in their long night of half a month, they must be extremely in want of the light reflected from the earth, unless the inhabitants have the faculty of sleeping through the whole of their dark fortnight. The surface of the moon appears to be very rocky and barren, and liable to frequent disturbances from volcanoes. These have been supposed to project some of their contents within the reach of the earth's attraction, which they might easily do, if they could throw them out with a velocity of about eight thousand feet in a second, which is only four times as great as that of a cannon ball; and these stones, falling through the atmosphere, might very possibly generate so much heat, by compressing the air, as to cause the appearance of fiery meteors, and to fall in a state of ignition. The appearance of the moon, as viewed through a good telescope, is extremely well imitated by Mr. Russel's lunar globe, which is also capable of exhibiting, with great accuracy, the changes produced by its librations."

The same valuable writer offers the following useful remarks

upon other phænomena of the planets, and their variations of brightness and eclipses.

"The revolutions of the primary planets, combined with that of the earth, necessarily produce the various relations, in which they are either in opposition or conjunction, with respect to each other or to the sun, and in which the apparent motion is direct or retrograde, or the planet is stationary, according to the directions and the comparative velocities of the real motions. If the earth were at rest, the inferior planets would appear to be stationary when they are at the greatest elongation or angular distance from the sun; but, on account of the effect of the earth's motion, Venus is stationary at an elongation of about 29°, while her greatest elongation is between 45° and 48°. The greatest elongation of Mercury, in each revolution, is from 28½° to 17½°, according to the position of his orbit, which is very eccentric. All these appearances are precisely the same as if the sun actually revolved round the earth, and the planets accompanied him in his orbit, performing at the same time their several revolutions round him; and the path which would thus be described in the heavens, and which is of a cycloidal nature, represents correctly the true positions of the planets with respect to the earth. The apparent angular deviation from the ecliptic, or the latitude of the planet, is also greater or less, accordingly as the earth is nearer or remoter to the planet, as well as according to the inclination of its orbit, and its distance from the node.

"The various appearances of the illuminated discs, especially of the inferior planets, and the transits of these planets over the sun, depend on their positions in their orbits, and on the places of the nodes, with respect to earth. Jupiter, Saturn, and the Georgian planet, are so remote in comparison of the earth's distance from the sun, that they appear always fully illuminated. Venus is brightest at an elongation of about 40° from the sun, in that part of her orbit which is nearest to the earth; she then appears like the moon when 5 days old, one-fourth of her disc being illuminated; she casts a shadow, and may even be seen in the day time in our climates, if she happens to be far enough north: a circumstance which occurs once in about 8 years. In order that there may be a transit of Venus over the sun, she must be within the distance 1¼° of her node at the time of conjunction, otherwise she will pass either to the north or to the south of the sun, instead of being immediately interposed between him and the earth.

The phases and eclipses of the moon are very obviously owing to the same causes; that part of the moon only, on which the sun shines, being strongly illuminated, although the remaining part is faintly visible, by means of the light reflected on it from the earth; it is, therefore, most easily seen near the time of the new moon, when the greatest part of the earth's surface turned towards the moon is illuminated. The parts of the moon which are immediately opposed to the earth, appear to undergo a libration, or change of situation, of two kinds, each amounting to about 7 degrees; the one arising from the inequality of the moon's velocity in her orbit at different times, the other from the inclination of the axis of her rotation to her orbit; besides these changes, the diurnal rotation of the earth may produce, to a spectator situated on some parts of it, a third kind of libration, or a change of almost two degrees in the appearance of the moon at her rising and setting.

"When the moon passes the conjunction, or becomes new, near to the node, she eclipses the sun, and when she is full, or in opposition, in similar circumstances, she herself enters the earth's shadow. The earth's shadow consists of two parts, the true shadow, within which none of the sun's surface is visible, and the penumbra, which is deprived of a part only of the sun's light; the true shadow forms a cone terminating in a point at a little more than 3½ times the mean distance of the moon; the penumbra, on the contrary, constitutes, together with the shadow, a portion of a cone diverging from the earth without limit; but the only effect of this imperfect shadow is, that it causes the beginning of a lunar eclipse to be incapable of very precise determination; for the limit of the darkened part of the moon, as it appears in the progress of the eclipse, is that of the true shadow, very little enlarged by the penumbra. The true shadow, where the moon crosses it, is about 80 minutes in diameter, as seen from the earth, while the moon herself is only 30. This shadow is not, however, wholly deprived of the sun's light; for the atmospheric refraction inflects the light passing nearest to the earth, in an angle of 66 minutes, and causes a great part of the shadow to be filled with light of a ruddy hue, by means of which the moon remains still visible to us, the cone of total darkness extending to somewhat less than two-thirds of the moon's distance. But it has sometimes happened, probably from the effect of clouds occupying the greatest part of our atmosphere, that the moon has totally disappeared.

"When the sun is eclipsed, it depends on the situations of the earth and moon in their orbits, whether the sun or moon subtends the greatest angle as seen from the earth; since at their mean distances their apparent diameters are each about half a degree. If the sun's apparent diameter is the greater, the eclipse, when the centres coincide, must be annular, the margin of the sun's disc being still visible in the form of a ring: when the moon's apparent diameter is greater than the sun's, the eclipse, if central, becomes total: but still a ring of pale light is seen round the disc, which has been attributed to the effect of the sun's atmosphere, since that of the moon is probably too inconsiderable to produce the appearance: a red streak is also sometimes observed at the margin, before the actual emersion of the sun. The degree of darkness depends on the situation of the place of observation within the shadow, on account of the greater or less illumination of the atmosphere within view; sometimes a considerable number of stars may be seen during a total eclipse of the sun.

"It is obvious that, since the earth is much larger than the moon, the whole shadow of the moon will only pass over a part of the earth's surface; and that no solar eclipse can be visible in the whole of the hemisphere turned to the sun: while lunar eclipses, on the contrary, present the same appearance wherever the moon is visible. In the same manner, to a spectator on the moon, an eclipse of the earth, or a transit of the moon's shadow over the earth's disc, would have nearly the same appearance wherever he might be stationed; but an eclipse of the sun by the earth would be total to that part of the moon's surface only, which to us appears dark at the same time.

"The moon's nodes arrive very nearly at the same situation with respect to the earth after 223 lunations, or revolutions of the moon, which are performed in 18 years of 365 days each, 15 days, 7 hours, and $43\frac{3}{4}$ minutes; so that after a period of about 18 years, the series of eclipses recommences nearly in the same order. This circumstance was observed by the ancients, and is mentioned by Ptolemy and by Pliny. When the full moon happens within $7\frac{1}{2}°$ of the node, there must be a lunar eclipse, and there may be an eclipse at the distance of 13° from the node. An eclipse of the sun may happen when the moon changes, or comes into conjunction with the sun, at any distance within $17\frac{1}{2}°$ of the node. The mean number of eclipses which occur in a year is about 4; and there are sometimes as many

as 7; there must necessarily be two solar eclipses, but it is possible that there may not be even one lunar. In speaking of the magnitude of the part of the sun or moon eclipsed, it is usual to consider the whole diameter as divided into twelve parts, called digits, each of which contains thirty minutes; thus if one-fifth part of the diameter were dark, the extent of the eclipse would be called 2 digits 12 minutes.

"The moon travels through the heavens with a motion contrary to their apparent diurnal revolution. Hence she rises and sets, on an average, about three quarters of an hour later every day. The least possible difference between the times of the moon's rising on two successive days, is, in London, 17 minutes; and this circumstance occurs once in about 19 years, which is nearly the period of the moon's nodes with respect to the heavens; the greatest possible difference is 1 hour 17 minutes. But it happens every month that the difference becomes greater and less by turns, and when the least difference is at the time of the full moon, it is usually called the harvest moon. In parts nearer to the poles, the moon often rises at the same hour on two succeeding days.

"The eclipses of the satellites of Jupiter exhibit appearances extremely interesting for their utility in identifying the same instant of time in different places. On account of the small inclination of their orbits to the plane of Jupiter's orbit, the first three never pass the shadow without being plunged into it, and the fourth but seldom; while those of Saturn are much less frequently liable to be eclipsed, on account of their greater deviation from the plane of his ecliptic. These satellites are also frequently hidden behind the body of the planet, and this circumstance constitutes an occultation; hence it happens that we can never see both the immersion of the first satellite into the shadow of Jupiter, and its emersion from it; but both the immersion and emersion of the three outer satellites are sometimes observable. The ring of Saturn exhibits a variety of forms according to its angular position; it disappears to common observation when either its edge or its dark side is presented to us; but to Dr. Herschel's telescopes it never becomes invisible; the light reflected from the planet being probably sufficient for illuminating in some measure the side not exposed to the sun's direct rays.—Nat. Phil. Vol. I. p. 527.

In a total eclipse of the sun, 12 May, 1706, a streak of light was observed 6″ or 7″ before the sun's disc; hence Flamstead infers a lunar atmosphere $\frac{1}{180}$th of the moon's diameter in height; but this might have been from oblique reflection.—Phil. Trans. 1706.

During a total eclipse of the moon, Ulloa observed that there was a great appearance of light round the moon, which seemed to be agitated, and emitted rays to the distance of a diameter; it was reddish next the moon, then yellowish. Stars of the first and second magnitude were seen, those of the first for about 4 minutes. A minute and a quarter before the emersion, a small point was visible near the disc of the moon. From the ruddy colour of the light, the ring is referred to the moon's atmosphere; the spot to a fissure in the moon's substance. Such a fissure must have been above 40 miles in depth.—Phil. Trans. 1779.

The Egyptians reckoned by years of 365 days; Hipparchus and Ptolemy employ the same method. In A.D. 940, the first day of the Egyptian year, was the first of January; another Egyptian year began 31 December. In the new stile, 10 days were omitted in 1582; before this time, each century contained 36,525 days.—Robinson.

To find the prime number, sometimes called the solar cycle, add 9 and divide by 28; the indiction, add 3 and divide by 15. Add 1 to the year and divide by 19, the remainder is the golden number, take 1 from the golden number, multiply by 11, and divide by 30, the remainder is the epact, or the moon's age, on the first of January.—Lalande.

In astronomical language, 1 Jan. 1805, 6 o'clock A.M. is 1804, Dec. 31d. 18h.—Lichtenberg.

CHAP. XXIII.

STARS VISIBLE IN LONDON, INCLUDING ALL OF THE FIRST AND SECOND MAGNITUDE.

When a spherical surface has been projected on a plane, it has been usual to consider it as viewed from a particular point, either

infinitely remote, as in the orthographical projection, or situated in the opposite surface of the sphere, as in the stereographical. The latter method produces the least distortion, and is the most commonly used, but even here, at the extremities of the hemisphere, the scale is twice as great as in the middle. Sometimes another principle is employed, and the hemisphere is divided into segments, by omitting portions in the directions of their radii, as if the paper were intended to be fixed on a globe; and in the same form as if a spherical surface were cut in the direction of its meridians, and spread on a plane. If the number of these divisions be increased without limit, the result will be the projection, which is employed in the circular part of this diagram, and in the same manner the zone on each side the equinoctial, being cut open by innumerable divisions, so as to be spread on a plane, will coincide with the two remaining portions. By these means the distortion becomes inconsiderable. In the common stereographical projection indeed, the distortion would be of no consequence, if it represented always those stars only, which are at once above the horizon of a given place, for we actually imagine the stars in the zenith to be much nearer together, than when they are nearer the horizon, and the picture would appear to agree very well with the original; but their positions being continually changing, the inconvenience remains.

It is not however, necessary, in projections of the stars, to refer them in any instance to a spherical surface. Among Dopplemayer's charts, published at Nuremberg, there are six which represent the sides of a cube, on which the various parts of the constellations are represented; the eye being probably supposed to be situated in the centre. Funck and others have represented the stars as projected on the inside of two flat cones. But the most convenient representation of this kind, and which would approach very near to the projection here employed, would be to consider the eye as placed in the centre of a hollow cylinder, so proportioned that all the circumpolar stars should be represented on one of its flat ends, and all those which rise and set on its concave surface; or if it were desired to have a division without referring to any particular latitude, the circular part might extend to the limits of the zodiac, and the parallelogram, into which the cylinder unfolds, might comprehend all

the stars to which the planets approach. The horizon, and other great circles, would form lines of various and contrary curvatures.

Ursa major	B, C, 5.	Pleiades	E, 3.	Arcturus	B, 7.
Ursa major	C, 5.	Aldebaran	D, 3.	Scorpio	C, 9.
Cassiopeia	E, 5.	Menkar *	E, 2.	Libra	B. 8, 9.
Capella	D, 4.	(Canopus)		Corona borealis	B, 7.
Algenib	D, 4.	Aries	F, 3.	Hercules	C, 7.
Algol	E, 4.	Orion	D. 2.	Serpentarius	C, 7.
Cygnus	D, 6.	Castor	C, 3.	Aquila	D, 8.
Lyra	D, 8.	Procyon	C, 2.	Pegasus	F, 7.
Draco	C, D, 5, 6.	Sirius	C, 1.	Fomalhaut	F, 9.
Cepheus	D, 5.	Regulus	B, 2.	(Centaurus	**).
Andromeda	E, 4, F, 3, 7.	Spica	A, 8.	(Crux	†).

[*Young's Nat. Phil.* II. 328].

CHAP. XXIV.

ON THE FUTURE PROGRESS OF ASTRONOMY.

From the preceding observations, it has sufficiently appeared that the immense globe of the sun, the focus of all the motions of the heavenly bodies, revolves upon its axis in twenty-five days and a half. Its surface is covered with an ocean of luminous matter, whose active effervescence forms variable spots, often very numerous, and sometimes larger than the earth. Above this ocean exists an immense atmosphere, in which the planets, with their satellites, move, in orbits nearly circular, and in planes little inclined to the ecliptic. Innumerable comets, after having approached the sun, remove to distances, which evince that his empire extends beyond the known limits of the planetary system. This luminary not only acts by its attraction upon all these globes, and compels them to move around him, but imparts to them both light and heat; his benign influence gives birth to the animals and plants which cover the surface of the earth, and analogy induces us to believe, that it produces similar effects on the planets; for, it is not natural to suppose that matter, of which we see the fecundity develop itself in such various ways, should be sterile upon a planet so large as Jupiter, which, like the earth, has its days, its nights, and his years, and on which observation discovers changes that indicate very active forces. Man, formed for the temperature which he enjoys upon the earth, could not, according to all appearance, live upon the other planets; but ought there not to be a diversity of organization suited to the various temperatures of the globes of this universe? If the difference of elements and climates alone, causes such variety in the productions of the earth, how infinitely diversified must be the productions of the planets and their satellites? The most active imagination cannot form any just idea of them, but still their existence is extremely probable.

However arbitrary the system of the planets may be, there exists between them some very remarkable relations, which may throw

light on their origin; considering them with attention, we are astonished to see all the planets move round the Sun from west to east, and nearly in the same plane all the satellites moving round their respective planets in the same direction, and nearly in the same plane with the planets. Lastly, the sun, the planets, and those satellites in which a motion of rotation has been observed, turn on their own axis, in the same direction, and nearly in the same plane as their motion of projection.

A phenomenon so extraordinary, is not the effect of chance; it indicates an universal cause, which has determined all these motions. To approximate somewhat to the probable explanation of this cause, we should observe that the planetary system, such as we now consider it, is composed of seven planets, and fourteen satellites. We have observed the rotation of the sun, of five planets, of the moon, of Saturn's ring, and of his farthest satellite; these motions with those of revolution, form together thirty direct movements, in the same direction. If we conceive the plane of any direct motion whatever, coinciding at first with that of the ecliptic, afterwards inclining itself towards this last plane, and passing over all the degrees of inclination, from zero to half the circumference; it is clear that the motion will be direct in all its inferior inclinations to a hundred degrees, and that it will be retrograde in its inclination beyond that; so that, by the change of inclination alone, the direct and retrograde motions of the solar system, can be represented. Beheld in this point of view, we may reckon twenty-nine motions, of which the planes are inclined to that of the earth, at most $\frac{1}{4}$th of the circumference; but, supposing their inclinations had been the effect of chance, they would have extended to half the circumference, and the probability that one of them would have exceeded the quarter, would be $1-\frac{1}{2^9}$, or $\frac{536870911}{536870912}$. It is then extremely probable, that the direction of the planetary motion is not the effect of chance, and this becomes still more probable, if we consider that the inclination of the greatest number of these motions to the ecliptic, is very small, and much less than a quarter of the circumference.

Another phenomenon of the solar system equally remarkable, is the small eccentricity of the orbits of the planets and their satellites, while those of comets are much extended. The orbits of the system offer no intermediate shades between a great and small excentricity. We are here again compelled to acknowledge the effect

of a regular cause; chance alone could not have given a form nearly circular, to the orbits of all the planets. This cause then must also have influenced the great eccentricity of the orbits of comets, and, what is very extraordinary, without having any influence on the direction of their motion; for, in observing the orbits of retrograde comets, as being inclined more than 100° to the ecliptic, we find that the mean inclination of the orbits of all the observed comets, approaches near to 100°, which would be the case if the bodies had been projected at random.

Thus, to investigate the cause of the primitive motions of the planets, we have given the five following phænomena: 1st, The motions of planets in the same direction, and nearly in the same plane. 2d, The motion of their satellites in the same direction, and nearly in the same plane with those of the planets. 3d, The motion of rotation of these different bodies, and of the sun in the same direction as their motion of projection, and in planes but little different. 4th, The small eccentricity of the orbits of the planets, and of their satellites. 5th, The great eccentricity of the orbits of comets, although their inclinations may have been left to chance.

Buffon is the only one whom I have known, who, since the discovery of the true system of the world, has endeavoursd to investigate the origin of the planets, and of their satellites. He supposes that a comet, in falling from the sun, may have driven off a torrent of matter, which united itself at a distance, into various globes, greater or smaller, and more or less distant from this luminary. These globes are the planets and satellites, which, by their cooling, are become opaque and solid.

This hypothesis accounts for the first of the five preceding phænomena; for, it is clear that all bodies thus formed, must move nearly in the plane which passes through the centre of the sun, and in the direction of the torrent of matter which produces them. The four other phænomena appears to me inexplicable by his theory. In fact, the absolute motion of the particles of a planet would then be in the same direction of the motion of its centre of gravity; but it does not follow that the rotation of the planet would be in the same direction. Thus, the earth may turn from west to east, and yet the absolute direction of each of its particles may be from east to west. What I say of the rotatory motion of the planets, is equally applicable to the motion of their satellites in their orbits, of which

the direction in the hypothesis he adopts, is not necessarily the same with the projectile motion of the planets.

The small eccentricity in the motion of the planetary orbits, is not only very difficult to explain on this hypothesis, but the phenomenon contradicts it. We know by the theory of central forces, that if a body moving in an orbit round the sun, touched the surface of this luminary, it would uniformly return to it at the completion of each revolution; from whence it follows, that if the planets had originally been detached from the Sun, they would have touched it at every revolution, and their orbits, far from being circular, would be very eccentric. It is true, that a torrent of matter, sent off from the sun, cannot correctly be compared to a globe which touches its surface. The impulse which the particles of this torrent receive from one another, and the reciprocal attraction exercised among them, may change the direction of their motion, and increase their perihelion distances; but their orbits would uniformly become very eccentric, or at least it must be a very extraordinary chance that would give them eccentricities so small as those of the planets. In a word, we do not see, in this hypothesis of Buffon, why the orbits of about eighty comets, already observed, are all very elliptical. This hypothesis, then, is far from accounting for the preceding phænomena. Let us see if it is possible to arrive at their true cause.

Whatever be the nature of this cause, since it has produced or directed the motion of the planets and their satellites, it must have embraced all these bodies; and considering the prodigious distance which separates them, it can only be a fluid of immense extent. To have given in the same direction, a motion nearly circular round the sun, this fluid must have surrounded the luminary like an atmosphere. This view, therefore, of planetary motion, leads us to think, that in consequence of excessive heat, the atmosphere of the sun originally extended beyond the orbits of all the planets, and that it has gradually contracted itself to its present limits, which may have taken place from causes similar to those which made the famous star that suddenly appeared in 1572, in the constellation Cassiopeia, shine with the most brilliant splendour during many months.

The great eccentricity of the orbits of comets, leads to the same result; it evidently indicates the disappearance of a great number

of orbits less eccentric, which intimates an atmosphere round the sun, extending beyond the perihelion of observable comets; and which, in destroying the motion of those which have traversed it in a duration of such extent, has re-united them to the sun. Thus, we see that there can at present only exist such comets as were beyond this limit at that period. And as we can observe only those which in their perihelion approach near the sun, their orbits must be very eccentric: but, at the same time, it is evident that their inclinations must present the same inequalities as if the bodies had been sent off at random, since the solar atmosphere has no influence over their motions. Thus, the long period of the revolutions of comets, the great eccentricity of their orbits, and the variety of their inclinations, are very naturally explained by means of this atmosphere.

But how has it determined the motions of revolution and rotation of the planets? If these bodies had penetrated this fluid, its resistance would have caused them to fall into the sun. We may then conjecture, that they have been formed at the successive bounds of this atmosphere, by the condensation of zones, which it must have abandoned in the plane of its equator, and in becoming cold have condensed themselves towards the surface of this luminary. One may likewise conjecture, that the satellites have been formed in a similar way by the atmosphere of the planets. The five phænomena, explained above, naturally result from this hypothesis, to which the rings of Saturn add an additional degree of probability.

Whatever may have been the origin of this arrangement of the planetary system, which I offer with that distrust which every thing ought to inspire that is not the result of observation or calculation; it is certain that its elements are so arranged, that it must possess the greatest stability, if future observations do not disturb it. Through this cause alone, that the motions of planets and satellites are nearly circular, and impelled in the same direction, and in planes differing but little from each other, it arises that this system can only oscillate to a certain extent, from which its deviation must be extremely limited; the mean motions of rotation and revolution of these different bodies are uniform, and their mean distances to the foci of the principal forces which animate them, are uniform. It seems that nature has disposed every thing in the heavens to insure

the duration of the system by views similar to those which she appears to us so admirably to follow upon the earth, to preserve the individual and insure the perpetuity of the species.

Let us now look beyond the solar system. Innumerable suns, which may be the foci of as many planetary systems, are spread out in the immensity of space, and at such a distance from the earth, that the entire diameter of it, seen from their centre, is insensible. Many stars experience both in their colour and splendour, periodical variations, very remarkable; there are some which have appeared all at once, and disappeared after having for some time spread a brilliant light. What prodigious change must have operated on the surface of these great bodies, to be thus sensible at the distance which separates them from us, and how much they must exceed those which we observe on the surface of the sun? All these bodies which are become invisible, remain in the same place where they were observed, since there was no change during the time of their appearance; there exist then in space obscure bodies as considerable, and perhaps as numerous as the stars. A luminous star, of the same density as the earth, and whose diameter should be two hundred and fifty times larger than that of the sun, would not, in consequence of its attraction, allow any of its rays to arrive at us; it is therefore possible that the largest luminous bodies in the universe, may, through this cause, be invisible. A star, which, without being of this magnitude, should yet considerably surpass the sun, would perceptibly weaken the velocity of its light, and thus augment the extent of its aberration. This difference in the aberration of stars and their situation, observed at the moment of their transient splendour, the determination of all the changeable stars, and the periodical variations of their light; in a word, the motions peculiar to all those great bodies, which, influenced by their mutual attraction, and probably by their primitive impulses, describe immense orbits, should, relatively to the stars, be the principal objects of future astronomy.

It appears that these stars, far from being disseminated at distances nearly equal in space, are united in various groups, each consisting of many millions of stars. Our sun, and the most brilliant stars, probably make part of one of these groups, which, seen from the point where we are, seems to encircle the heavens, and forms the milky way. The great number of stars which are seen at once in

the field of a large telescope, directed towards this way, proves its immense depth, which surpasses a thousand times the distance of Sírius from the earth; as it recedes, it terminates, by presenting the appearance of a white and continued light of small diameter; for then, the irradiation which exists even in the most powerful telescopes, covers and obscures the intervals between the stars. It is then probable, that those nebulæ, without distinct stars, are groups of stars seen from a distance, and which, if approached, would present appearances similar to the milky way.

The relative distances of the stars which form each group, are at least a hundred thousand times greater than the distance of the sun from the earth. Thus, we may judge of the prodigious extent of these groups, by the number of stars which are perceived in the milky way: if we afterwards reflect on the small extent and infinite number of nebulæ which are separated from one another by an interval incomparably greater than the relative distance of the stars of which they are formed; the imagination, lost in the immensity of the universe, will have difficulty to conceive its bounds.

From these considerations, founded on telescopic observations, it follows, that nebulæ, which appear so well defined, that their centres can be precisely determined, are, with regard to us, the celestial objects most fixed, and those to which it is best to refer the situation of all the stars. It follows then, that the motions of the bodies of our solar system are very complicated. The moon describes an orbit nearly circular around the earth; but, seen from the sun, she describes a series of epicycloids, of which the centres are on the circumference of the terrestrial orbit. In like manner, the earth describes a series of epicycloids, of which the centres are on the arch which the sun describes around the centre of gravity of our nebulæ; finally, the sun himself describes a series of epicycloids, of which the centres are on the arch described by the centre of gravity of our nebulæ around that of the universe. Astronomy has already made one great step in making us acquainted with the motion of the earth, and the series of epicycles which the moon and the satellites describe upon the orbits of the planets. It remains to determine the orbit of the sun, and the centre of gravity of its nebulæ; but, if ages were necessary to become acquainted with the motions of the planetary system, what a prodigious duration of time will it require to determine the motions of the sun and stars? Observa-

tion begins to render them perceptible; an attempt has been made to explain them by a change of position in the sun, indicated by its rotatory motion. Many observations are sufficiently well explained, by supposing the solar system carried towards the constellation Hercules. Other observations seem to prove, that these apparent motions of the stars are a combination of their real motion with that of the sun. Upon this subject, time will discover curious and important facts.

There still remains numerous discoveries to be made in our own system. The planet Uranus and its satellites, but lately known to us, leave room to suspect the existence of other planets, hitherto unobserved. We cannot yet determine the rotatory motion, or the flattening of many of the planets, and the greatest part of their satellites. We know not, with sufficient precision, the density of all these bodies. The theory of their motions is a series of approximations, whose convergence depends, at the same time, on the perfection of our instruments, and the progress of analysis, and which must, by these means, daily acquire new degrees of correctness. By accurate and repeated measurement, the inequalities in the figure of the earth, and the variation of weight on its surface, will be determined. The return of comets, already observed, new comets which will appear, the appearance of those, which, moving in hyperbolic orbits, can wander from system to system, the disturbance all those stars experience, and which, at the approach of a large planet, may entirely change their orbits, as is conjectured happened by the action of Jupiter on the comet of 1770; the accidents, that the proximity, and even the shock of these bodies, may occasion in the planets, and in the satellites; in a word, the changes which the motions of the solar system experience with respect to the stars; such are the principal objects which the system presents to astronomical researches, and future geometricians,

Contemplated as one grand whole, astronomy is the most beautiful monument of the human mind; the noblest record of its intelligence. Seduced by the illusions of the senses, and of self-love, man considered himself for a long time as the centre of the motion of the celestial bodies, and his pride was justly punished by the vain terrors they inspired. The labour of many ages has at length withdrawn the veil which covered the system, Man appears, upon a small planet, almost imperceptible in the vast extent of the

solar system, itself only an insensible point in the immensity of space. The sublime results to which this discovery has led, may console him for the limited place assigned him in the universe. Let us carefully preserve, and even augment the number of these sublime discoveries, which form the delight of thinking beings.

They have rendered important services to navigation and astronomy; but their great benefit has been the having dissipated the alarms occasioned by extraordinary celestial phænomena, and destroyed the errors springing from the ignorance of our true relation with nature; errors so much the more fatal, as social order can only rest in the basis of these relations. TRUTH, JUSTICE; these are its immutable laws. Far from us be the dangerous maxim, that it is sometimes useful to mislead, to deceive, and enslave mankind, to insure their happiness. Cruel experience has at all times proved, that with impunity these sacred laws can never be infringed.

[*La Place, Système du Monde.*]

CHAP. XXV.

HISTORY OF SYSTEMATICAL PHSYSICS.

THOUGH we commonly give the appellation of systems to the different suppositions by which Ptolemy, Copernicus, and Tycho Brahe, have endeavoured to account for the course of the heavens, it is not what we now mean by general and systematical physics. We are upon a philosophy which undertakes to explain the profound construction of the whole universe. The project is noble: four or five celebrated philosophers have employed themselves in it; they have made numerous parties, and many disputes. The history of their pretensions may determine us in the choice of the best side, or in remaining entirely neuter.

Epicurus, reviving the ideas of Leucippus and Democritus, thought he very well comprehended that particles of matter different in form, having subsisted from all eternity, had, after a certain time, linked themselves to one another in the vacuum; that some pro-

ceeding in straight lines, and others in curves, fell into different clusters, and formed bodies and spirits: that the free agency of man was, above all, the work of atoms which moved in a declining line: thus chance made the sun, peopled the earth, established the order which subsists in it *: and framed, out of one and the same paste, the world, and the intelligent being, which is the spectator of it: that we are not to imagine the sun was made to light us, or our eyes to

* Atheism does not appear to have extended so far as is here conceived: and it is due to the character of Epicurus, and is demanded of us by the candour of genuine philosophy, to observe, that the common opinion that this great supporter of the atomic sect supposed the visible universe to have been produced by chance, has no foundation in any part of his writings that have descended to our day, and is in many passages most peremptorily contradicted by them. "Whom," says Epicurus, in a letter to Menœceus, preserved in Diogenes Laertius, "do you believe to be more excellent than he who piously reveres the gods, who feels no dread of death, and rightly estimates the design of nature? Such a man does not, with the multitude, regard Chance as a God, for he knows that God *can never act at random*; nor as a *contingent* cause of events; nor does he conceive that from any such power flows the good or the evil that attempers the real happiness of man." So, in another passage of another letter, "Believe, *before all things*, that God is an immortal and blessed being; as indeed common sense should teach us concerning God. Conceive nothing of him that is repugnant to blessedness and immortality, and admit every thing that is consistent with these perfections."

In common, however, with Aristotle and most of the other philosophers of Greece, Epicurus conceived that perfect rest and quiet were essentially necessary to the perfect happiness of the great Creator; and he hence supposed that all the phænomena of the natural, and all the events of the moral world, are perpetually taking place without any direct interference or general providence of the Deity, since this, in his opinion, would be to produce a disturbance in the calm of his essential felicity; but at the same time that they do not take place at random, or by chance or accident, but under the control of a general system of laws established at the beginning, and on the formation of the world. To which opinion he expressly alludes in the following passage from another letter preserved by Diogenes Laertius: "Think not that the different motions and revolutions of the heavens; the rising, setting, eclipses, and other phænomena of the planets are produced by the *immediate* control, superintendance, or ministration of him who possesses all immortality and beatitude; it is from the *immutable laws* which they received at the beginning, in the creation of the universe, that they inflexibly fulfil their various circuits!

For a further account of this subject we refer the reader to Mr. Good's elaborate examination of it in his Life of Lucretius, prefixed to his translation of the NATURE OF THINGS, to which indeed we are indebted for these extracts.—*Editor.*

by a proper manuduction transmute it into gold. What riches! what felicity and assistance to human society! should we once arrive to this point.

If the systematical philosophers think rightly on the article of a first matter, in which they all agree, the alchymists think still better in reducing these speculations to practice, and attempting to change this matter so, as to produce gold and immortality.

Unluckily for the honour of philosophers, alchymists die; and not only so, but they sooner than others. The greater number of them are parched among their furnaces and pestiferous exhalations; but this is certain, they all ruin themselves. Their fruitless attempts prove the falsity of the principle which they had from the philosophers, and dispense with our entering into a tedious examination of this imaginary philosophy.

It is sufficient to be thoroughly sensible of the great mistake of systematical philosophers, to know that they form the world with a matter void of form, which at first was neither water, fire, metal, earth, nor any thing now apparent; and that afterwards, by motion, it became all that we now see. Daily experience shows them all, if they will see, that to bring to light, and to multiply the transient species which maintain the seed of the world for the duration of ages, God has prepared a vast variety of simple natures, which never proceeded from a first matter different from themselves. That these natures have no other immediate cause of their formation than God himself; that they never pass from a first state to a second; that they are unchangeable as he is, who gave them being; that no motion can alter, change, or convert them into other natures, or resolve them into other things than what they are: they can neither be destroyed nor forced; and since the most violent motion can have no such effect on them, they cannot owe their particular nature to any turn, or bias, which has been given them by motion. Let us judge of it by some experiments. Put refined gold into a most intense fire, it will continue in fusion for several months together. A violent fire, which, according to the Cartesians, is only a violent motion, ought now, as well as in the beginning of the world, to cause some little novelty in this matter. 'Tis certainly more easy to destroy than to form. Why cannot then this motion, which from the first matter produced gold, by force of graduating and varying, destroy this gold in the crucible, or convert it into some new being, or

at length reduce it into a small portion of the first matter? Do not the philosophers perceive that they take methodical ideas, by which they dispose every thing in the schools, for realities subsisting in nature, while they have being in their own imagination only? They employ their thoughts on matter in general, afterwards on matter determined in particular. Do they therefore believe that there is, or that there ever was, an universal matter? They are indeed notable in seeking the analysis of gold, and reducing it to its first principles, to carry it back to the first matter. They may as well analyse flowers in the chemist's furnace, in hopes of finding in the last dissolution an universal flower at the bottom of the receiver.

In the same manner put into the fire sand, mud, mercury, or any metal you shall think proper, the sand will become glass by the congruity it acquires in the fire; and after having been years together in a glass-house pot, it will still be glass; the mud will fall into lime or ashes, and will never, after a separation of its parts, be other than cinders, or a *caput mortuum*. Mercury mixed with sulphur, and all the ingredients that can be thought upon, will always remain in cinnabar, or some other form. It will be lost to sight, but neither destroyed nor changed. It is always entire under new forms, always the same, and fire will restore it back in its pristine form. 'Tis the same thing with metals. Torture them, give them what motion, what alteration you can devise, by fire, aqua fortis, or other dissolvents, they have not even one moment changed their nature. If we put a piece of iron into aqua fortis, in which was before dissolved a certain quantity of silver, it cannot sustain parcels of two different metals at the same time; it quits the silver, falsely thought to be transmuted into a liquid, which precipitates to the bottom of the vessel.

It was only concealed in floating on the globular parts of the fluid, by a separation of the metallic parts; but these small particles thus separated, are still the same as when united in one mass. The minium, with which we colour wafers, is made with lead; the metal is no longer apparent; one would think it was destroyed, or converted into another nature. It is more separated, but the particles are not changed; and if you burn this wafer in the flame of a candle, and catch the cinders on a piece of paper, you will see the particles of lead, when in fusion, drawn near to one another, and form, when cold, several shining branches, easy to be distinguished by the naked

eye. Gold and metals extracted out of matters, where nothing metallic is to be seen, are not there formed; it is true, they are there found, and they are extracted from the places to which the water had carried and dispersed them: hence it comes, that gold is found along the river sides, and in sands likewise; iron in clay; and the particles of iron which adhere to a knife touched with a loadstone, stirring with it the ashes of plants, flesh, or the entrails of animals. The metallic, saline, earthy, sandy, aquatic, ignetic, mercurial, and many other simple particles, go off and return, form masses, appear under very different figures, are concealed, and then again apparent; but gold, iron, earth, water, sand, fire, mercury, and in short all simple matters, are ever exactly the same thing, whether in small or great bodies. The natures of each are to themselves the first matter; and as the most agitated and varied motion cannot resolve them into other than what they are, they do not owe their construction to motion either direct, oblique, or circular. They have all immediately proceeded, as did the whole world, from the hand of God himself. They are not what they become by the combination of motions, but what God willed at first they should be, to serve in the formation of compounded bodies, to which his wisdom had appointed them. Gold, or crystal, is not now made: but only carried, gathered together, dispersed; wherefore motion, which never has been able to produce the least grain, has not been able, *a fortiori*, to produce either an earth, or its inhabitants, an atmosphere or a sun. Motion maintains the earth, but never could ordain it; as the spring of a watch, and the care of winding it up every day, is the cause of its going regular, but cannot make it. It is then the part of a prudent philosopher to study those motions which maintain nature, as they are real, regular, and lasting; but it is making an abuse of reason, it is despising of experience, and may be secretly reviving the follies of the Epicureans, to attribute to motions impressed on matter the power of forming a world. It is as impossible for motion to form a world, as it is evidently impossible for it to form a grain weight of iron.

As it is but loss of time for us to stir the atoms of Gassendi, or to whirl about the angular bodies of Descartes, we shall possibly find the attractive, centripetal, and centrifugal philosophers of the north turn to better account.

The difference between M. Descartes and Sir Isaac Newton is,

that the former undertakes to account for every thing; and the other, modestly acknowledging that we are ignorant of the secrets of nature, pretends only to evince one matter of fact, without undertaking to explain the cause; but as this one point extends, according to him, to all nature, his system for that reason becomes a kind of universal philosophy. According to M. Descartes, that gravity which causes bodies to fall, is nothing different from the action of the fluids, in which the planets are carried away; because all bodies moved and impelled by the bodies surrounding them, to describe a circular instead of a straight line, incessantly endeavour to recede from the centre; whence it happens, that when the parts of the vortex meet with the bodies which have no centrifugal force, or which have less, they are compelled to fly to the centre; so that the precipitation of heavy bodies towards the centre, is nothing but the action of more active bodies which have a tendency to avoid it. Sir Isaac Newton at first thinks with M. Descartes, from whom he had learned it, that all bodies continue in a state of inaction, or repose, till drawn out of it or interrupted.

Again, Sir Isaac Newton imagines, that he has observed throughout all nature, and it is the distinguishing point of his system, that all bodies attract one another in proportion to their distance and bulk; that they have a certain tendency towards, and press one upon another; that the sun tends towards the earth, and the earth towards the sun; but that the latter being incomparably larger, we perceive only the approaches of the former towards it: that in like manner the earth tends towards the stone which is separated from it by projection, as the stone tends towards the earth, or rather that the stone attracts the earth to it, as the earth attracts the stone; but the earth, by reason of its bulk, having a stronger attraction than a small stone, it happens from thence, that the earth does not quit its place, and that the stone approaches, or is drawn to it by the attractive power which the earth exercises upon it.

This action, which Newton imagines he every where perceives between bodies and bodies, throughout all nature, he calls *attraction*, and gives it out as an effect residing in every part of the universe, without being able to assign other cause than the will of God to put all nature in motion. Thus the earth moved round the sun, if it was only moved, and not drawn towards it, would infinitely recede from it. The moon, if it obeyed without obstacle the law of mo-

tion which carries it away, would avoid the earth, and at length disappear. In the same manner, if the earth obeyed only the law of attraction, that law by which the sun draws the earth to it, it would draw near to, and precipitate into the sun; the moon being only attracted, would fall upon the earth: but the earth being moved and cast off from the sun, is at the same time drawn toward it; instead of receding from it in a straight line, this line will be curved by the attraction which brings it back to the sun: being always under the influence of two powers, one of which always removes it from the sun, and the other draws it back; it describes round the sun a curved line, which Newton demonstrates ought to be an ellipsis, or near to an oval. The moon, in like manner, obeying two powers, one which makes it fly from, the other which makes it tend towards the earth, circulates round it; the centrifugal and the centripetal forces are checks one upon the other; and the moon, instead of being carried far from us by the first power, or precipitated upon our earth by virtue of the second, is, by the impression of both, kept within its orbit.

Sir Isaac Newton afterwards examines what would be the measures of motion of the moon beginning to fall towards the earth, from the height of its orbit, after it had lost its centrifugal force, and was freed from all attraction of the earth. The distance of the moon from the earth is known, also the duration of its revolution; one may then know what is the portion of the orbit in a minute. Geometry teaches us what space the moon runs through in a right line falling towards the earth, by virtue of the force which makes it pass through his arch, or portion of its orbit. Afterwards, having laid it down, that the attraction diminishes as the square * of the distance increases, Newton finds by his calculations, that the moon in falling from its station, would at first fall fifteen feet in a minute; and that near the earth, by virtue of the same law, it would in a minute pass through three thousand six hundred times fifteen feet. Lastly, examining the spaces which a body of wood or stone let fall, would pass through near the earth, he concludes from the experience

* They call any number multiplied by itself a square. If the interval between the earth and moon be divided into three strata, the first has for its square 1, the second 4, the third 9. The attraction diminishing in proportion as the squares of the distances increase, will act as 9 in the first stratum, as 4 in the second, and 1 in the third.

gained by the fall of bodies, that a stone runs in one minute, near our globe, through three thousand six hundred times fifteen feet. The moon being loosed from its orbit, would therefore obey the same law which precipitates the stone. By a necessary consequence, if the stone was carried as high as the orbit of the moon, being there let fall, it would run through fifteen feet in a minute. Attraction and gravity are then one and the same thing.

M. Privat de Molieres, of the Academy of Sciences, has retained, in his Philosophical Lectures, the ground-work of Newton's observations. He admits all the proofs which show that the same cause which makes a stone gravitate upon the earth, makes the earth gravitate upon the sun, and the moon upon the earth; but he attributes this effect to a cause very different from that which Newton has imagined. The French academician, at the same time that he extols the exactness of the geometrical system of the learned Englishman, finds it incompatible with the plan of nature. He is not reconciled to a principle which makes of our world, one *All*, whose parts are as naked, and less united than those of a skeleton. All the ideas which we have of mechanics, seem to him to be overthrown by this imaginary attraction, which, according to the partisans of the English geometrician, reciprocally acts between bodies separated by a great vacuum, and makes them move in a void, without uniting by any intermediate bond. M. Molieres resumes the vortex of M. Descartes; the existence of which seems to him to be almost palpably nature. He corrects it in the whole; and making all the effects which Newton had observed, to flow from the very structure of the vortex, he in some measure reconciles the two contending schools.

This vortex is no longer composed, as Descartes had imagined, of hard and inflexible globules, but of small vortices, the particles of which are incessantly inclining to recede from their peculiar centre, while the whole tends to remove from the common centre. A solid body, as the moon or earth, cast into this vortex, ought immediately to be moved by it, and carried the same way with it; but the parts of this unwieldy body being strictly united, and at rest among themselves, make no effort for motion, and have no other impulsion than what the whole body of the planet receives from the vortex in which it floats; whereas the globules of the vortex have a double motion, and make a double effort; all of them tend to remove from the common centre, the moment they are forced, by the surrounding

vortices, to move in a circular line. Moreover, all the particles of these globules perform that in little, round their centre, which the great ones do in general round their common centre. From this double tendency, results a double force, which more powerfully removes them from the centre, than the motion impressed on the planet removes it from the centre of the sphere. The planet cast into this voxtex, has indeed received a centrifugal force, in receiving a circular motion; but its parts being at rest, it has less centrifugal force than the vortex, in which this force is double, as well from the motion of the little vortices which fly from the common centre, as their particles, which all at the same time avoid their respective centres. Thus the centrifugal force in the matter of the vortex exceeding the centrifugal force of the planet, ought to prevail: and the planet tending less to recede from the centre, than the matter which pushed it on, it must follow, that the earth will by degrees draw nearer to the sun, and the moon fall upon the earth. In a word, Des Molieres makes use but of one action, or same cause, to produce the centrifugal force of the vortex, and to make the planets, and all solid bodies, gravitate to one and the same centre: instead of which, Newton adds a motion impressed on all these bodies; another power and another law, which he names *attraction*, and which disposes them all to draw near to one another, with more or less velocity, in proportion to their solidity, or their distances; while, indeed, the second power is useless and inconceivable.

M. de Molieres, after having given us this assistance, by his ingenious explanation of gravity, to comprehend the double centrifugal force of vortices, and the advance of solid bodies towards the centre, as a simple effect of this force, left us at first in doubt of the power he would make use of to sustain the planets in their orbit, and to prevent their falling upon the centre. But it was easy to perceive, at the same time that he would be compelled to make use of different vortices, at least of different atmospheres, cast round the planets, to make them roll one over another, without falling, like the globules of different matter, which, crowding together, flatten a little by their pressure upon each other; while in the interim, the centres which tend one towards another, by the impulsion of the encompassing vortices, can never approximate.

This explanation of M. de Molieres is so much the more ingenious as it is not made use of for the creation of a world, but to

give an idea of its motion and support, as it may be employed in the particular explanation of a number of phænomena, and of particular cases; such, for example, as the flux and reflux of the sea, by the pressure of the sphere of the moon on that of the earth; the shifting of the satellites of Jupiter, by the pressure of the sphere of Saturn on that of Jupiter; the attractions and repulsions of electric bodies, by the small atmospheres which they acquire or lose, according to the different manner they are touched; the dissolutions and fermentations in chemistry, by the different powers of the little vortices which compose liquids, and which can only appear at rest, when they are put in equilibrio, after a long agitation, occasioned by inequality of efforts.

I shall not here touch upon the systems which M. Huygens, Bulfinger, Bernouilli, and many others have imagined on gravity; it is but a point of the mechanics of the universe. Should we ask fifty philosophers an explanation of them, there is not one of them but would believe that he gave you a philosophy that was to be esteemed in proportion to the geometry and calculations he had employed in it. Even all these indefatigable calculations will often, setting out with the same principles, lead you to as many different sums, different mechanisms, and to as many systems, as there are different persons whom you consult. What will be the consequence, when, from this point, we go on to an explanation of the bolsters of the axis, and the profound structure of the other parts of the universe. Entering into these systematical opinions, will be quitting a view of nature, and losing sight of the certain use which we may make of it, and in which consists our true philosophy. Another reason to keep us upon our guard with relation to systems is, that however beautiful they may appear at first sight, the application we may make of them to different effects, generally turns out unlucky and ridiculous. Make use, for example, of the system of attraction, on the pheuomenon of the loadstone, where one would think it ought to be of great use; or to electricity; or to what is called fermentation; you will find that your principle will leave you in the lurch, and will inform you in nothing; they are obliged to vary their attractions like their effects. Here, it is an attraction which acts through the whole depth of the mass there, it is an attraction which only acts on the slightest superfices of the body, let them be thin or thick; there, a certain attraction is the same, while another attraction varies, as does the

diversities of the bodies. But above all, the attractionists were in raptures with that which they perceived, or thought they perceived, in electrical bodies. This could not be mistaken, and it acted exactly as in the planets, diminishing in the circuit, as it augmented in distance. Unluckily an experimental philosopher came and knocked all this on the head; and by fastening a little ball of wood at the extremity of a cord of a thousand or twelve hundred feet long, he discovered, that if an electrical tube was applied either to the middle or at one end of this cord, the spangles of gold placed at the other end, under the wooden ball, clung to it as suddenly as if the electricity had acted within a foot of the tube. One of our learned Newtonians* has made an hundred experiments upon the loadstone. After infinite precautions and calculations, he frankly owns the attraction failed him, when he had occasion for it, and that he could make nothing of it†.

I shall here end the history of systematical philosophy, because it is of little use to give a more full knowledge of it, and perhaps may be dangerous to young people, by busying their minds upon systems, which cannot fail, in spite of all our exertions, to present some phænomena to our thoughts, which is a very great prejudice to the progress of true philosophy; either because it is not easy to get rid of certain generalities, or that we see every thing conformable to our prejudices. Experimental philosophy is the only one which has been of use to human society; and as we have shown that the advantages flowing from it are innumerable, so we cannot recommend for the study of philosophy, a more prudent method than that which the members of the Royal Academy have followed for our instruction.

* Mr. Muschenbroek.

† These considerations the reader will find more minutely examined in the introductory chapter to the department of CHEMISTRY, which will enter into the second division of the present work. It will there appear that many of the objections here offered to the simplicity of the general, and now still farther established laws of nature, have been removed by experiments and observations not known at the time the ingenious paper here copied was written: and that most, if not all, the peculiar attractions of matter are resolvable into different modifications of the general attraction of gravitation.

It is to the second part of the present work that we have also to refer the reader for an account of such astronomical instruments, maps, charts, globes, orreries, and projections, as are most curious or in other respects worthy of notice.—Editor.

They have never, as a collective body, given their approbation to any one general system. They are fully persuaded, that if man be allowed to arrive at a thorough knowledge of nature, it can be only by treasuring up experiments and facts, for a great length of years; and should even this thorough knowledge be denied to our condition, experiments at least, and the knowledge of most minute things, will procure, as is daily experienced, various benefits to public society. This very judicious principle, which they have always looked upon as a rule, and the nature of the different functions which these learned men have divided among themselves, are accurately founded on the necessaries of life, and the extent of our capacities. They go farther: the experimental philosophy which they have brought into esteem is the only useful one, because it is the only one conformable to our condition: which, without offence, we may name, *The System of Providence.*

The experience of six thousand years is certainly sufficient to teach us what is possible and what is forbidden. While man, in his inquiries, was busied in things submitted to his government, his endeavours were always rewarded by new discoveries. Whenever he would pry into the interior structure of the parts of the universe, the motion of which is not submitted to his care, his ideas have been fantastical and uncertain. Let him study the measures of magnitudes, and the laws of motions; not to pace out the heavens, or to weigh the solid bodies of the planets, but to know the order of his days; let him observe the relation of the aspects of the heavens to his habitation, the progression of light in the modification in which it is presented to him; the use he may make of the equilibrium of liquids, of the weights and velocities of the bodies of which he is master, of all the experiments which come within his view, and especially under his hand; in a word, let him apply experiments to the necessaries of life, and he will have an unerring philosophy, replete with great advantages. But to undertake to determine the cause which governs the motion of the universe, and to penetrate into the universal structure, and the particular parts of which it is composed, is to forfeit the honour of improving his patrimony in order to run after shadows. It is neglecting treasures which are open to us, and obstinately persisting to knock at a door which has been shut against us these six thousand years.

This is no conjectural opinion, but a visible truth of experience, that God has given us great facility and intelligence in things which we ought to manage; and, on the contrary, that those to which God

himself gives motion and action, without entrusting the conduct to our care, he has concealed from our knowledge. For example, we are ignorant of the structure of our stomach, because God has eased us of the care of its digestion. In vain would the most able anatomist direct his digestion; all very often goes contrary to his wishes. On the other hand, we have in our senses many watchful and faithful monitors, opportunely to direct what nourishment is proper for us. Why then have we so many methods to be acquainted with our nutriment, if it is not that the care of seeking and chusing it, is committed to us? And why, on the contrary, do we not know how to digest, if it be not that God has evidently willed our digestion to be performed in us without our direction? God, who has spared us that trouble, has denied us the knowledge of the mechanism which forms the flesh and the fruits that we eat, as well as the mechanism which extracts the juices from them for our nourishment. This knowledge would have distracted us. We attain the age of four score and ten, without knowing what digestion is, or what is the action of the muscles. We have been served without any care on our part. Had we thoroughly known the structure of our stomachs, we should have been for directing its functions. God has not allowed this knowledge to man. He ordained him to be otherwise employed. If then this mechanism be hid from him, lest it should multiply his cares, will he acquaint him with the structure of the world, the motion of which is not committed to his charge?

I can scarcely be of opinion, that the modern philosophers have rightly conceived the plan of the Creator, in having less esteem for the knowledge which we attain by our senses, than for what they imagine is to be acquired by a profound meditation. One example will make me understood.

The common sailor knows nothing more of the loadstone than what his senses inform him, viz. its tendency towards the north pole. This is the sum of his knowledge. The philosopher would know the cause of this phenomenon; he employs the effluvia of its pores in spiral lines, the attractions, the repulsions; and after several years use of his mechanics, his geometries and calculations, he either acknowledges that he himself knows nothing of the matter, or else has the mortification to find that nobody approves of his system. The systematical philosopher, who thinks himself ignorant if he know not the cause of what he sees, passes his whole life in the pursuit of *possibilities*, and becomes useless to the rest of mankind by being buried

alive in his closet. The sailor makes use of what his senses inform him of, the direction of the loadstone towards the north, and by its assistance voyages to the end of the world. Make choice of ten thousand other informations of fact, and you will hardly find one of them but what is of service. Our fortunes will be better in proportion to this sort of knowledge. Would you seek after the causes of these effects? You will meet with nothing of certainty or use. Can we, after this, mistake the intention of God, in the measure of understanding which he affords us for our present instruction?

It is evident that we have no universal knowledge. The objects of our pursuit are scattered round us upon the earth and in the heavens. God has given us, together with eyes and understanding, a fund of curiosity which stimulates us from one object to another, that new experiments may enable us to procure new conveniencies for our brethren; and that every thing upon earth may, by degrees, be put to the best use for the profit of mankind. But though a man can go on a stretch from Brest to Pekin, it does not follow that he can go to the moon; or though he have a principle of power in his hands, that enables him to support piles of oak, and great blocks of marble in the air, this is no reason why he should attempt with his levers to make the moon fly off from her orbit, or to fix his pullies to the body of Jupiter, to rob him of one of his satellites. As man's strength is limited, so likewise is his knowledge, and these bounds are suited to his wants. He meets with opposition every where, when he enters upon idle speculations. But he proceeds from discovery to discovery, which discoveries work miracles, when he employs himself in making the best use of that which is about him. Our reason is always attended with success in uniting the truths of experience with the necessities of life, in making a prudent use of the benevolence of the Creator, and in giving him the glory. This is the sum total of human knowledge.

[*Abbé Le Pluche. Spec. de la Nature.*]

We have given the above, not because we approve of the philosophy of the vortices, but as containing a tolerably fair view of the theories that preceded it; and a curious specimen of the different modes by which this philosophy was adhered to, in opposition to the doctrine of universal attraction, as long as it could possibly be defended.—*Editor.*

BOOK II.

GEOLOGY.

CHAPTER I.

GEOGNOSY; OR, THE DOCTRINE OF THE ORIGIN AND GENERAL STRUCTURE OF THE EARTH.

UNDER the Wernerian system of Mineralogy, the term *Geology* is altogether relinquished, or only incidentally referred to, as importing abstract and imaginary speculations concerning the formation of the Earth: while the immediate branch of science, designed to be glanced at in the present chapter, is denominated *Geognosy*. We have no objection to the last term in the sense thus signified; but shall restore the term *Geology*, and employ it, as its derivation will readily justify our doing, in a classific form, importing the general *doctrine of the earth* in its insentient or unorganized frame; and consequently as comprising equally its *subterranean*, *superficial*, and *atmospherical* phænomena.

Before we enter, however, upon these particular parts of our subject, it becomes us to offer a brief view of what, so far as we are capable of determining from an actual survey of nature, appears to have been the origin of the earth, as to its present structure and constitution, comprising that introductory branch of geological science, which, as we have already observed, professor Werner has distinguished by the name of *Geognosy*.

The object of Geognosy is to unfold the general make of the globe; to discover by what causes its parts have been arranged; from what operations have originated the general stratification of its materials, the inequalities with which its surface is diversified,

and the immense number of different substances of which it is composed.

In pursuing this investigation, many difficulties occur to us. The bare surface or mere crust of the solid substance of the earth is the whole that we are capable of boring into, or of acquiring a knowledge of, even by the deepest clefts of volcanoes, or the bottoms of the deepest seas. It is not often, however, that we have a possibility of examining either seas or volcanoes at their bottom; the inhabitable part of the globe bears but a small portion to the uninhabitable, and the civilized an infinitely smaller proportion still. Hence, our experience must be necessarily extremely limited; a thousand facts may be readily conceived to be unfolded that we are incapable of accounting for, and a variety of theories are daily disappearing while other theories are starting up in their stead.

So far as the superficies of the earth has been laid open to us by ravines, rivers, mines, &c. we find it composed of stony masses, sometimes simple, as lime-stone, serpentine, or quartz; but more frequently compound, or composed of two or more simple materials, variously mixed and united together, as granite, which is a composition of quartz, felspar, and mica. These stony masses, or rocks, are numerous, and they appear to be laid one over the other, so that a rock of one kind of stone is covered by another species of rock, and this by a third, and so on. In this superposition of rocks, it is easily observable, that their situation is not arbitrary; every stratum occupies a determinate place, so that they follow each other in regular order from the deepest part of the earth's crust, which has been examined, to the very surface. Thus there are two things respecting rocks, that peculiarly claim our attention; their composition and their relative situation. But, besides the rocks which constitute the earth's crust, there are other masses which must also be considered. These traverse the rocks in a different direction, and are known by the name of veins, as if the rocks had split asunder in different places from top to bottom, and the chasms had been afterwards filled up with the matter which constitutes the vein.

Independently of the substances thus presented to us, we meet with facts that prove most decisively that the general mass has undergone various revolutions at various times, and revolutions not only of great antiquity, but of universal extent. We have the most

unexampled proof, that its whole surface has been covered with water, and that every part of it has suffered change; mountains have been raised, plains levelled, islands separated from a continent, and the waters collected so as to leave an elevated land. We find it difficult to conceive causes adequate to the production of such effects; and operations so immense seem too remote from any means of investigation which we possess, to admit of being explained.

One point, however, in the midst of all the intricacy that surrounds us still remains decided, that the shell of the globe has, at some period or other, been in a state of fluidity, and that from this circumstance has arisen its present arrangement. Now the only two causes that can enter into the mind of man as being competent to such an effect are, the operation of fire, or of some solvent; and hence our researches become in some degree limited to the inquiry by which of these means this effect has been induced. If a solvent have been the cause, that solvent must have been water, for there is no other fluid in nature in sufficient abundance to have acted the part of a solvent upon a scale so prodigious.

Hence, then, two distinct theories arise, which appear to have been agitated with considerable warmth in former times, but with a much greater degree of warmth, and much deeper view of the subject, in the present day. Is the present structure of the solid contents of the earth, so far as it is capable of examination, the result of igneous fusion, or of aqueous solution? Is the Plutonic or the Neptunian system founded on the strongest basis? In ancient times Heraclitus took the lead as to the former; and Thales, or rather, perhaps, Epicurus, as to the latter. In our own period, though the Plutonic theory was first revived by M. Buffon, or rather perhaps by Hooke, its defenders are now chiefly confined to our own country, and consist of Dr. Hutton, professor Playfair, and very lately of Sir James Hall; names unquestionably highly respectable, and entitled to every deference, but most powerfully opposed by the respectable authorities of Werner, De Saussure, and Kirwan, not to mention that the general voice of geologists is very considerably in favour of the Neptunian theory, or that entertained by the last-mentioned philosophers.

Plutonic Theory.—1. According to this system there is in the substance either of the entire globe, or throughout the entire crust

of it with which we are acquainted, a regular series of decay and renovation, and the processes by which these are affected have an uniform relation to each other. The hardest rocks are worn down by air and water, causes which, however slowly they may operate, are constant in their action, and which, therefore, in indefinite time, must be equal to the production of the greatest effect. From the figure of the surface of the earth, the decayed materials must be carried towards the ocean, and ultimately deposited in its bed. This transportation may be impeded by local causes, or may, in general, be extremely slow, yet from the declivity of the land it must necessarily take place, and may, therefore be admitted as an uniformly operating cause.

2. It is further assumed, that at certain depths in the mineral regions an immense heat is constantly present; a heat which operates in the fusion and consolidation of the substances deposited in these regions. To the action of this subterraneous fire the formation of all our strata is attributed, for by this they are again sublimed, and exposed to view in different states of combination and perfection. These strata, therefore, consist of the wrecks of a former world, which have been more or less completely fused by this agent, and by subsequent cooling have been consolidated.

The subterraneous fire to which these effects are ascribed is conceived to operate under the modification of compression, in consequence of which, from various facts appealed to, and to a certain extent confirmed by some very valuable experiments by Sir James Hall, (provided those experiments should bear the test of farther enquiry) it seems pretty clearly ascertained, that when certain gasses appertaining to the fusible substance, as carbonic acid for example, are rendered incapable of flying off, a much less quantity of actual heat is sufficient for the purpose of fusion, than when such gasses, freed from a heavy superincumbent pressure, have a possibility of escaping. Now the subterraneous fire being placed at immense depths, the substances on which it operates must be enormously compressed; which compression will prevent their volatilization in whole or in part: and from this circumstance it is possible, we are told, to explain appearances and qualities in minerals, and to answer various objections, which would otherwise weigh heavy against the hypothesis.

3. The elevation of the strata is in like manner the result of this

same subterraneous heat: and it is contended that nothing but the extensive and forcible power which is hereby produced can be fairly conceived adequate to such an effect.

The first of these positions is not very objectionable, and as far as relates to its general principle, separated from the positions with which it is connected, may be admitted. It may be allowed by the Neptunian as well as by the Plutonic geologist, that the strata of the earth are liable to waste, and that the materials are carried forward to the sea: but the appearance of lime-stones and marbles containing shells, in which the sparry structure is as perfect as it is in the primary lime-stone, and in which are distributed veins of crystallized carbonate of lime, this, and a variety of facts like this, must at all times militate fatally against the agency of fire in the production of such sparry structure, and such veins of crystallization; for in every instance in which it is found sufficient to produce such a structure, it must necessarily have destroyed every vestige of the structure of the shells, and have altogether dissipated the carbonic acid, necessary for the veins of crystallized carbonate of lime.

Against the second position the objections are indeed strong, and, if we mistake not, insuperable. "It is not fire, says Mr. Playfair, in the usual sense of the word, but heat, which is required for this purpose; and there is nothing chimerical in supposing that nature has the means of producing heat, even in a very great degree, without the assistance of fuel, or of vital air. Friction is a source of heat, unlimited, for what we know, in its extent; and so perhaps are other operations, both chemical and mechanical; nor are either combustible substances or vital air concerned in the heat thus produced. So also, the heat of the sun's rays in the focus of a burning glass, the most intense that is known, is independent of the substance just mentioned; and though the heat would not calcine a metal, nor even burn a piece of wood, without oxygenous gas, it would doubtless produce as high a temperature in the absence as in the presence of that gas." From these and other experiments, he concludes, "that it not absurd to suppose, that the heat of great, dense, and fixed bodies may be consumed by the greatness of the bodies, and the mutual action and reaction between them and the heat they emit."

In reply to this argument, which we admit, is very ingeniously conducted, it is forcibly asked, by the author of the Comparative

View of the two systems, in direct reply to Mr. Playfair's Illustrations of the Huttonian Theory, "To what purpose are the various sources of heat enumerated in this reasoning? To prove that it may exist, or be produced independant of burning. This will be readily granted; but the reasoning can prove nothing farther. It can be satisfactorily shewn that any of the known causes of heat are as incapable of producing it in the interior parts of the globe, to that extent which must be supposed in the Huttonian theory, as combustion, which, even by its defenders, is confessed to be inadequate to that purpose."

In regard to the third general position, that the strata, after having been fused and consolidated by subterranean heat, are elevated by the same power, the same general objection is applicable, which has been already urged against the preceding principle, viz. the difficulty or impossibility of obtaining and preserving a degree of heat sufficient for such a purpose. And even were this granted, no principle is pointed out in the theory, by which the action of such a power can be regulated; why it may not anticipate or be too late for its due season of action, and be as often the cause of havoc and disorder, as it is asserted to be the regular and pre-ordained instrument of the renovation of a continent. Hence the principle assumed is at once gratuitous and improbable.

In a work restricted, like the present, to narrow extent in the discussion of the different articles of which it is composed, it is always a point of very considerable consequence to detect insuperable objections to a system *in limine;* for it enables a writer to appropriate many of his pages, which would otherwise be devoted to the same subject, to inquiries of more importance, because vested on a firmer foundation. If the objections to the Plutonic theory, as already urged, few as they are, be conceived decisive (and we can scarcely imagine any other verdict from our readers), we may well be saved the trouble of pointing out those inconsistencies it labours under, as well in regard to the actual *position* of many of the stony rocks of the globe contemplated in mass, as in the appearances and properties of individual fossils: though we feel persuaded that the arguments resulting from a minute investigation into both these points, would be altogether as complete as in the question of principle. It is sufficient, however, to observe, that notwithstanding its magnificence of structure, and extent of application, notwithstand-

ing the speciousness of its first introduction, and the talents with which it has been supported, the Plutonic theory is built upon assumption alone. It lays down principles which it cannot support, and in stating observations to other theories, it rather clears the way for the advance of something unborn than establishes its own positions.

Neptunian theory.—Under this view of the origin and structure of the globe, less superb indeed, but possessing a much wider appeal to facts than the preceding, it is conceived that aqueous solution has been the agent by which the phænomena on the superficies of the globe have been produced. It is conceived that the materials of which our strata consist were at one time dissolved or suspended in water, and that from this fluid they have successively consolidated in various combinations, partly by crystallization, and partly by mechanical decomposition. Granite being the rock which composes the most elevated part of the globe, and which likewise forms the basis on which the greater number of the strata rest, is supposed to have been first formed, the different parts of which it consists, felspar, quartz and mica, having concreted by a crystallization nearly simultaneous. This is conceived to have been accompanied with, and followed by, a similar consolidation of the other primitive strata, gneis, micareous schist, argillaceous schist, porphyry, quartz, &c.

Those rocks compose the chief elevations of the globe. They are never found to contain any organic remains, and of course their formation must have been prior to the existence of the vegetable and animal kingdoms,

From the period of the formation of these strata, it is contended that the water covering the surface began to diminish in height by retiring gradually into cavities in the internal parts of the earth. And if we may be permitted to recur, by an effort of the imagination, to that epocha in which, according to sacred and profane historians, the water and earth were confounded, and the confused mixture of all principles formed a chaos, we shall see that the laws of gravity inherent in matter must have carried it down, and necessarily produced the arrangement which observation at present exhibits to us. The water, as the least heavy, must have purified itself, and arisen to the surface by a filtration through the other materials: while the earthy principles must have precipitated, and formed a mud, in which all the elements of stones were confounded.

In this very natural order of things, the general law of affinities, which continually tends to bring together all analogous parts, must have exerted itself with its whole activity upon the principles of this almost fluid paste, and the result have been a number of bodies of a more definite kind, in crystals more or less regular; and from this muddy substance, in which the principles of the stones were confounded that compose the granite, a rock must have been produced, containing the elementary stones all in possession of their distinct forms and characters. In this manner it is that we observe salts of very different kinds develop themselves in waters which hold them in solution; and in this manner it still happens that crystals of spar and gypsum are formed in clays which contain their component parts.

It may easily be conceived that the laws of gravitation must have influenced the arrangement and disposition of the products. The most gross and heavy bodies must have fallen, and the lightest and most attenuated substances must have arranged themselves on the surface of the foregoing; and this it is which constitutes the primitive schists, the gneis, the rocks of mica, &c. which commonly repose upon masses of coarse-grained granite. The disposition of the fine-grained granite in strata or beds, appears to depend on this position, and the fineness or tenuity of its parts. Being placed in immediate contact with water, this fluid must naturally have influenced the arrangement which it presents to us; and the elements of this rock, being subjected to the effect of waves, and the action of currents, must have formed strata.

The rocks of granite being once established as the ground work of the superficies of our globe, we may, from the analysis of its constituent principles, and by attending to the action of the various agents capable of altering it, follow the changes to which it has been subjected, step by step.

Water is the principal agent whose effects we shall examine. This fluid, collected in the cavity of the ocean, is carried by the atmosphere to the tops of the most elevated mountains, where it is precipitated in rain, and forms torrents, which return with various degrees of rapidity into the common reservoir. The uninterrupted motion and fall must gradually attenuate and wear away the hardest rocks, and carry their detached parts to distances more or less considerable. The action of the air, and the varying temperature of the

atmosphere, facilitate the attenuation and the destruction of these rocks. Heat acts upon their surface, and renders it more accessible and more penetrable to the water which succeeds; cold divides them, by freezing the water which has entered into their texture; the air itself affords the acid principle, which attacks the limestone, and causes it to effloresce; the oxygen unites to the iron, and calcines it: insomuch that the concurrence of causes favours the disunion of principles; and consequently the action of water, which clears the surface, carries away the products of decomposition, and makes preparation for a succeeding process of the same nature.

The first effect of the rain is therefore to depress the mountains. But the stones which compose them must resist in proportion to their hardness; and we ought not to be surprised when we observe peaks which have braved the destructive action of time, and still remain to attest the primitive level of the mountains which have disappeared. The primitive rocks, alike inaccessible to the injury of ages as to the animated beings which cover less elevated mountains with their remains, may be considered as the source or origin of rivers and streams. The water which falls on their summits flows down in torrents by their lateral surfaces. In its course it wears away the soil upon which it incessantly acts. It hollows out a bed, of a depth proportioned to the rapidity of its course, the quantity of its waters, and the hardness of the rock over which it flows; at the same time that it carries along with it portions and fragments of such stones as it loosens in its course.

These stones, rolled along by the water, must strike together, and break off their projecting angles: a process that must quickly have afforded those rounded flints which form the beds of rivers. These pebbles are found to diminish in size, in proportion to the distance from the mountain which affords them; and it is to this cause that Mr. Dorthes has referred the disproportionate magnitude of the pebbles which form our ancient worn stones, when compared with those of modern date; for the sea extending itself formerly much more inland, in the direction of the Rhone, the stones which it received from the rivers and threw back again upon the shores, had not run through so long a space in their beds as those which they at present pass over. Thus it is that the remains of the Alps, carried along by the Rhone, have successively covered the vast

interval comprised between the mountains of Dauphiny and Vivarais, and are carried into seas, which deposit them in small pebbles on the shore.

The pulverulent remains of mountains, or the powder which results from the rounding of these flints, are carried along with greater facility than the flints themselves: they float for a long time in the water, whose transparency they impair; and when these same waters are less agitated, and their course becomes slackened, they are deposited in a fine and light paste, forming beds more or less thick, and of the same nature as that of the rocks to which they owe their origin. These strata gradually grow drier by the agglutination of their principles; they become consistent, acquire hardness, and form siliceous clays, silex, petrosilex, and all the numerous class of pebbles which are found dispersed in strata, or in banks, in the ancient beds of rivers. The mud is much more frequently deposited in the interstices left between the rounded flints themselves, which intervals it fills, and there forms a true cement that becomes hard, and constitutes the compound stones known by the name of pudding-stones and grit-stones; for these two kinds of stones do not appear to differ but in the coarseness of the grain which forms them, and the cement which connects them together.

We sometimes observe the granite spontaneously decomposed. The texture of the stones which form it has been destroyed; the principles or component parts are disunited and separated, and they are gradually carried away by the waters. Water filtrating through mountains of primitive rock, frequently carries along with it very minutely-divided particles of quartz; and proceeds to form, by deposition, stalactites, agates, rock crystal, &c. These quartzose stalactites, differently coloured, are of a formation considerably analogous to that of calcareous alabasters; and we perceive no other difference between them than that of their constituent parts. Thus far we have exhibited, in a few words, the principal changes, and various modifications, to which the primitive rocks have been subjected: but we have not yet observed either germination or life; and the metals, sulphur, and bitumens, have not hitherto presented themselves to our observation. Their formation appears to have been posterior to the existence of this primitive globe; and the alterations and decompositions which now remain to be inquired

into, seem to have been produced by the tribes of living, or organised beings.

On the one hand, we behold the numerous class of shell animals, which cause the stony mass of our globe to increase by their remains. The spoils of these creatures, long agitated and driven about by the waves, and more or less altered by collision, form those strata and banks of lime-stone, in which we very often perceive impressions of those shells to which they owe their origin. On the other hand, we observe an enormous quantity of vegetables that grow and perish in the sea; and these plants, likewise deposited and heaped together by the currents, form strata, which are decomposed, lose their organization, and leave all the principles of the vegetable confounded with the earthy principle. It is to this source that the origin of pit-coal, and secondary schistus, is usually attributed; and this theory is established on the existence of the texture of decomposed vegetables very usually seen in schisti and coal, and likewise on the presence of shells and fish in most of these products. It appears that the formation of pyrites ought in part to be attributed to the decomposition of vegetables: it exists in greater or less abundance in all schisti and coal. A wooden shovel has been found buried in the depositions of the river De Ceze, converted into jet and pyrites. The decomposition of animal substances may be added to this cause; and it appears to be a confirmation of these ideas, that we find many shells passing to the state of pyrites.

Not only the marine vegetables form considerable strata by their decomposition; but the remains of those which grow on the surface of the globe ought to be regarded among the causes or agents which concur in producing changes upon that surface. We shall separately consider how much is owing to each of these causes; and shall follow the effects of each, as if that cause alone was employed in modifying and altering our planet.

1. The secondary calcareous mountains are constantly placed upon the surface of the primitive mountains; and though a few solitary observations present a contrary order, we ought to consider this inversion and derangement as produced by shocks which have changed the primitive disposition. It must be observed also, that the disorder is sometimes merely apparent; and that some naturalists of little information have described calcareous mountains as

inclining beneath the granite, because this last pierces through the envelope, rises to a greater height, and leaves at his feet, almost beneath it, the calcareous remains deposited at its base.

Sometimes even the lime-stone fills to a very great depth the crevices or clefts formed in the granite, sometimes schistus, or trap, occasionally containing petrifactions. These, in the Wernerian system, are called intermediate or transition rocks or strata. It likewise happens frequently enough that such waters as are loaded with the remains of the primitive granite heap them together, and form secondary granites which may exist above the calcareous stone. These calcareous mountains are decomposed by the combined action of air and water; and the product of their decomposition sometimes forms chalk or marle. The lightness of this earth renders it easy to be transported by water; and this fluid, which does not possess the property of holding it in solution, soon deposits it in the form of gurhs, alabasters, stalactites, &c. Spars owe their formation to no other cause. Their crystallization is posterior to the origin of calcareous mountains.

Waters wear down and carry away calcareous mountains with greater ease than the primitive mountains: their remains being very light, are rolled along, and more or less worn. The fragments of these rocks are sometimes connected by a gluten or cement of the same nature; from which process calcareous grit and breccias arise. These calcareous remains formerly deposited themselves upon the quartozes and; and the union of primitive matter and secondary products, give rise to a rock of a mixed nature.

2. The mountains of secondary schistus frequently exhibit to us a pure mixture of earthy principles, without the smallest vestige of bitumen. These rocks afford, by analysis, silex, alumina, magnesia, lime in the state of carbonate, and iron; principles which are more or less united, and consequently accessible in various degrees to the action of such agents as destroy the rocks hitherto treated of.

The same principles, when disunited, and carried away by waters, give rise to a great part of the stones which are comprised in the magnesian class. The same elements, worn down by the waters, and deposited under circumstances proper to facilitate crystallization, form the schorls, tourmaline, garnets, &c. We do not pretend by this to exclude and absolutely reject the system of such naturalists as attribute the formation of magnesian stones to the

decomposition of the primitive rocks. But we think that this formation cannot be objected to for several of them, more especially such as contain magnesia in the greatest abundance.

It frequently happens that the secondary schists are interspersed with pyrites; and, in this case, the simple contact of air and water facilitates their decomposition. Sulphuric acid is thus formed, which combines with the various constituent principles of the stone; whence result the sulphats of iron, of magnesia, of alumina, and of lime, which effloresce at the surface, and remain confounded together. Schists of this nature are wrought in most places where alum works have been established: and the most laborious part of this undertaking consists in separating the sulphats of iron, of lime, and of magnesia from each other, which are mixed together. Sometimes the magnesia is so abundant that its sulphat predominates. The sulphat of lime, being very sparingly soluble in water, is carried away by that liquid, and deposited to form gypsum, or the earth of plaster of Paris; while the other more soluble salts, remaining suspended, form vitriolic mineral waters. The pyritous schists are frequently impregnated with bitumen, and the proportions constitute the various qualities of pit-coal.

It appears that we may lay it down as an incontestable principle, that pyrite is abundant in proportion as the bituminous principle is more scarce. Hence it arises, that coals of a bad quality are the most sulphureous, and destroy metallic vessels, by converting them into pyrite. The foci of volcanoes appear to be formed by a schist of this nature; and in the analyses of the stony matters which are ejected, we find the same principles as those which constitute this schist. We ought not therefore to be much surprised at finding schorls among volcanic products; and still less at observing that subterranean fires throw sulphuric salts, sulphur, and other analogous products, out of the entrails of the earth.

3. The remains of terrestrial vegetables exhibit a mixture of primitive earths more or less coloured by iron: we may therefore consider these as a matrix in which the seeds of all stony combinations are dispersed. The earthy principles assort themselves according to the laws of their affinities; and form crystals of spar, of plaister, and even the rock crystals, according to all appearance: for we find ochreous earths in which these crystals are abundantly dispersed; we see them formed almost under our eyes. We have frequently

observed indurated ochres full of these crystals terminating in two pyramids.

The ochreous earths appear to deserve the greatest attention of naturalists. They constitute one of the most fertile means of action which nature employs; and it is even in earths nearly similar to these that she elaborates the diamond, in the kingdoms of Golconda and Visiapour.

The spoils of animals, which live on the surface of the globe, are entitled to some consideration among the number of causes which we assign to explain the various changes our planet is subjected to. We find bones in a state of considerable preservation in certain places; we can even frequently enough distinguish the species of the animals to which they have belonged. From indications of this sort it is that some writers have endeavoured to explain the disappearance of certain species; and to draw conclusions thence, either that our planet is perceptibly cooled, or that a sensible change has taken place in the position of the axis of the earth. The phosphoric salts and phosphorus which have been found, in our time, in combination with lead, iron, &c. prove that, in proportion as the principles are disengaged by animal decomposition, they combine with other bodies, and form the nitric acid, the alkalies, and in general all the numerous kinds of nitrous salts.

In examining, then, the merits of the antagonist systems of geology now offered, we have no objection to confess, that to the Huttonian belongs the praise of novelty, boldness of conception, and unlimited extent of view. It aspires not only to account for the present appearances of the earth, but to trace a plan by which the formation of successive worlds is developed: it seeks to extend that order and arrangement, that principle of balance and restoration observed in all the departments of nature, to the constitution of the globe *itself.*

With this system the Neptunian forms a perfect contrast. It presumes not to carry its researches beyond the commencement of the present world, or to extend them beyond its termination. All the phænomena of geology conspire to prove that water has been the great agent by which rocks have been formed, and the surface of the earth arranged. It does not pretend to deny the existence of subterranean fires to a certain extent, or that many of the phæno-

mena which strike us most forcibly may be the result of such an agency; but it does deny that such an agency is the grand or general cause of the geological facts and appearances that accost us on every side, and denies still farther that any such fire or heat can exist to an extent competent to such an extent. While the science remains in an imperfect state, deficiencies may be found in the application of its general principle. But we discover no inconsistencies with that principle, nor contradictions to known and established truths.

More especially do we feel disposed to adhere to this last theory from its general coincidence with the cosmogony of the Holy Scriptures. The Mosaic account indeed restrains the process of creation, and the period in which the waters covered the entire surface of the globe to a limit in which, "if the terms be understood in their strict and literal sense, the existing phænomena of nature seem to evince that they could not possibly have occurred: for it confines the entire work of creation within the compass of six days. In another part of the Scriptures, however, we have undeniable proofs that the term day, instead of being restrained to a single revolution of the earth around its axis, is used in a looser and more general sense, for a definite, indeed, but a much more extensive period: and we have as ample a proof from the book of nature, the existing face of the earth, that the six days or periods referred to in the Mosaic cosmology imply epochs of much greater duration than so many diurnal revolutions—as we have in the page of human history, that the same terms were employed with the same laxity of meaning by the prophet Daniel. Thus interpreted, scepticism is driven from her last and inmost fortress: every subterfuge is annihilated, and the word and work of the Deity are in perfect unison with each other. That the Creator might have produced the whole by a single and instantaneous effort, is not to be denied: but as both revelation and nature concur in asserting that such was not the fact, it is no more derogatory to him with whom a thousand years are but as one day, and one day as a thousand years, to suppose that he allotted six thousand years to the completion of his design than that he executed it in six days. And surely there is something far more magnificent in conceiving the world to have progressively attained form, order, and vitality, from the mere operation of powers com-

municated to it in a state of chaos, or unfashioned matter, than in supposing the actual and persevering exertions of the Almighty for a definite, although a shorter period of time.—*Editor*. See also *Good* and *Gregory's Pantalogia*, and *Comparative Statement of the Huttonian and Neptunian Systems of Geology*.

CHAP. II.

HISTORY OF THE GENERAL DELUGE, AND OPINIONS CONCERNING IT.

SIXTEEN hundred and fifty-six years after the earth was made and inhabited, it was overflowed and destroyed in a deluge of water: not a deluge that was national only, or over-ran some particular region; but that overspread the face of the whole earth, from pole to pole, and from east to west; and that in such excess, that the floods over-covered the tops of the highest mountains; the rains descending after an unusual manner, and the fountains of the great deep being broken open; so that a general destruction and devastation were brought upon the earth and all things in it, mankind and other living creatures; excepting only Noah and his family, who, by a special providence of God, were preserved in a certain ark, or vessel, with such kinds of living creatures as he took in with him. After these waters had raged for some time on the earth, they began to lessen and shrink; and the great waves and fluctuations of this deep, or abyss, being quieted by degrees, the waters retired into their channels and caverns within the earth; and the mountains and fields began to appear, and the whole habitable earth in that form and shape wherein we now see it. Then the world began again; and, from that little remnant preserved in the ark, the present race of mankind, and of animals, in the known parts of the earth, were propagated. Thus perished the old world, and the present arose from the ruins and remains of it.

This is a short story of the greatest event that ever happened in the world: the greatest revolution, and the greatest change in

nature: and which justly therefore deserves to be more particularly considered in all its circumstances.

That there was such an universal destruction by water, as is related by Moses, is confirmed by the concurrent testimonies of several of the most ancient writers and nations in the world. The Chaldean records give the following account of it, as they have descended to us from Berosus. Chronus or Saturn appeared in a dream to Xisuthrus, the tenth of the Chaldean kings, according to the table of Africanus, and warned him that on the fifteenth of the month Dæsius, mankind would be destroyed by a flood: and therefore commanded him to write down the original, intermediate state, and end of all things, and bury the writings under ground in Sippara, the city of the sun; that he should also build a ship, and go into it with his relations and dearest friends, having first furnished it with provisions, and taken into it fowls and four-footed beasts; and that when he had provided every thing, and was asked whither he was sailing, he should answer, 'To the gods, to pray for happiness to mankind.' Xisuthrus did not disobey, but built a vessel, whose length was five furlongs, and breadth two furlongs. He put on board all that he was directed, and went into it with his wife, children, and friends. The flood being come, and soon ceasing, Xisuthrus let out certain birds, which finding no food, nor place to rest upon, returned again to the ship. Xisuthrus, after some days, let out the birds again; but they came back to the ship, having their feet daubed with mud; but when they were let go the third time, they came no more to the ship, whereby Xisuthrus understood that the earth appeared again; and thereupon he made an opening between the planks of the ship, and seeing that it rested on a certain mountain, he came out with his wife, and his daughter, and his pilot; and having worshipped the earth, and raised an altar, and sacrificed to the gods, he, and those who went out with him, disappeared. They who were left behind in the ship, finding Xisuthrus and the persons that accompanied him, did not return, went out themselves to seek for him, calling him aloud by his name; but Xisuthrus was no more seen by them; only a voice came out of the air, which injoined them, as their duty was, to be religious; and informed them, that, on account of his own piety, he was gone to dwell with the gods; and that his wife and daughter, and pilot, were partakers of the same honour. It also directed them to return to Babylon, and that, as

the fates had ordained, they should take the writings from Sippara, and communicate them to mankind; and told them that the place where they were was the country of Armenia. When they had heard this, they offered sacrifice to the gods, and unanimously went to Babylon; and when they came thither, they dug up the writings at Sippara, built many cities, raised temples, and rebuilt Babylon.

That the Egyptians were no strangers to this event, appears not only from those circumstances in the story of Osiris and Typhon mentioned above, but from the testimony of Plato, who says, that a certain Egyptian priest recounted to Solon, out of their sacred books, the history of the universal flood, which happened long before the particular inundations known to the Grecians. The inhabitants of Heliopolis in Syria shewed a chasm or cleft in the earth in the temple of Juno, which, as they say, swallowed up the waters of the flood *. Nay, the very Americans are said to acknowledge and

* The author, who mentions this, says, the Greeks gave an account of the universal deluge (which they and others have confounded with that of Deucalion) too curious to be omitted. The tradition goes, proceeds he, that the present race of men was not the first, for they totally perished; but is a second series, which, being descended from Deucalion, increased to a great multitude. Now of these former men they relate this story: they were very insolent, and addicted to unjust actions; for they neither kept their oaths, nor were hospitable to strangers, nor gave ear to suppliants; for which reason this great calamity befel them. On a sudden the earth poured forth a vast quantity of water, great showers fell, the rivers overflowed, and the sea arose to a prodigious height; so that all things became water, and all men were destroyed: only Deucalion was left unto a second generation, on account of his prudence and piety. He was saved in this manner: he went into a large ark, or chest (λαρνακα) which he had, together with his sons and their wives; and when he was in, there entered swine and horses, and lions, and serpents, and all other creatures which live on the earth, by pairs. He received them all, and they did him no hurt, but the gods created a great friendship among them; so they sailed all in one chest while the water prevailed. These things the Greeks relate of Deucalion. But, as to what happened after this, there is an ancient tradition among those of Hierapolis, which deserves admiration; viz. that in their country a great chasm opened, and received all the water; whereupon Deucalion erected altars, and built the temple of Juno over the chasm. This same chasm, says our author, I have seen, and it is a very small one, under the temple; whether it was formerly bigger, and since lessened, I cannot tell; but that which I have seen is little. In commemoration of this history, they do thus: twice in every year water is brought from the sea to the temple, and not by the priests only, but all Syria and Arabia, many come from beyond Euphrates to the sea, and all carry water, which they first pour out in the

speak of it in their continent: and we are told, that there is a tradition among the Chinese, that Puoncu, with his family, escaped out of the general deluge; though another expressly asserts the Chinese annals make no mention at all of the flood, and that it is a mistake in those who imagine they do; however, it seems their historians do speak of a flood, which some suppose to be that of Noah, but they do not make it universal *. Most nations have some tradition of a deluge, which happened in their respective countries; but it must be owned at the same time, that several of them were particular inundations only, and ought therefore carefully to be distinguished from that of Noah; though ancient and modern writers frequently confound them together †, and relate circumstances of the one, which belong only to the other.

Some difficulties which seem to attend the Mosaic account of the deluge, such as the finding out waters sufficient to drown the world, and the improbability of all sorts of animals being preserved in the ark, have induced some, even men of learning, to suppose that Noah's flood was not universal, but national only, and confined to Judæa, and the circumjacent regions ‡, or perhaps to that track of land

---

temple, and afterwards it sinks into the chasm, which, though it be small, receives abundance of water. And when they do this, they say Deucalion instituted the ceremony in that temple, as a memorial of the calamity, and of his deliverance from it.

* An Arab, who travelled into China about the beginning of the ninth century, giving an account of a conversation he had with the Emperor, among other things, says, that mentioning the flood to that prince, on occasion of a picture of Noah which he shewed him, and telling him that that prophet, and those who were saved with him in the ark, peopled the whole earth; the Emperor laughed and said, "Thou art not deceived as to the name of Noah; but, as to the universal deluge, we know nothing of it. It is true, that the deluge did drown a part of the earth; but it did not reach so far as our country, nor yet to the Indies." Ebn Shoknah ranks the Chinese among those who deny the flood.

† Not only Deucalion's flood in Thessaly, but those of Ogyges in Attica, and Prometheus in Egypt, have been thought the same with that of Noah. Those spoken of by the Americans seem to have been national; as was that of Asia Minor, mentioned by Diodorus, from the Samothracian tradition, which yet they pretended was the most ancient of all; to omit several others enumerated by Sir W. Raleigh, some of which he has taken from the spurious Xenophon of Annius.

‡ Melo, who wrote a book against the Jews, speaking of the deluge, seems to make it topical, and not to have reached Armenia. His words are these:

which lies between the four seas, the Persian, Caspian, Euxine, and Mediterranean, or, at most, reached no farther than the continent of Asia. And, to support this presumption, they allege that, since the primary design of the flood was to destroy mankind only, who could hardly be thought in so short a time to have overspread the face of the whole earth, there was no necessity to carry the waters beyond the bounds of what was inhabited; and though in this case all the animals in the world (which were probably farther propagated than man, being created in greater numbers, and perhaps in divers parts) might not have been destroyed; yet it is conceived, that it was necessary to save some in the ark for future propagation, and that men might have them ready for their use presently after the flood, which could not otherwise have been. One author indeed has gone so far as to suppose, that all mankind did not perish in the deluge; and has endeavoured to prove, from a peculiar exposition of the curses of Cain and Lamech, that the Africans and Indians are of their posterity. But, as he has elsewhere himself confuted this opinion by the strongest arguments, we shall say no more of it. And it is easy to shew, against those who hold the former opinion, that they deny a matter of fact to get over a difficulty, and that the deluge was universal in its extent as well as effect.

For, first, the Scriptures put this matter out of doubt, by expressly telling us, that all the high hills under the whole heaven were covered by the waters, and that all flesh died that moved upon the earth, except only Noah, and those that were with him in the ark*. Nor

"At the time of the deluge, a man who had escaped with his sons, went from Armenia, being driven out of his possessions by those of the country; and, passing over the intermediate region, came into the mountainous part of Syria, which was then desolate."

* The words of Moses, one would think, are too plain to admit any subterfuge. God looked upon the earth; and behold it was corrupt; for all flesh had corrupted his way upon the earth. And God said unto Noah, the end of all flesh is come before me—and I will destroy them with the earth. Behold I, even I, do bring a flood of waters upon the earth, to destroy all flesh, wherein is the breath of life, from under heaven; and every thing that is in the earth shall die. Every living substance that I have made will I destroy from off the face of the earth. And the waters prevailed exceedingly upon the earth; and all the high hills, that were under the whole heaven, were covered. Fifteen cubits upward did the waters prevail; and the mountains were covered. And all flesh died that moved upon the earth, both of fowl and of cattle, and of beast and of every creeping thing that creepeth upon the earth, and every man,

will the terms of Moses allow the word earth in this place to be restrained, as it may in some others, to Judea*, or any other particular track of land: for, unless the laws of nature were miraculously suspended, before the waters in one region, much more on a whole continent, could exceed the tops of the highest mountains, they would certainly diffuse themselves, and overflow the rest of the earth. Secondly, if the deluge were topical, there was no need of the ark; Noah and his family needed only to have retired to another country, which he might have done with more ease, and in less time, than have built so vast a vessel; the beasts might have saved themselves by flight; or their loss, especially those of the unclean kinds, have been replenished from other places; and the birds might, without much difficulty, have flown to another continent. Thirdly, the number of mankind before the flood was vastly superior to what the present earth is, perhaps, capable of sustaining, according to various calculations: and the waters must therefore have overspread, in all probability, a larger part of the earth than is now known to be inhabited: and consequently the whole globe, that none might escape the Divine vengeance, must have been overflowed. Fourthly, the earth itself seems to offer us a demonstrative argument of the universallity of the deluge, from the vast number of the shells and teeth of fish, bones of animals, intire or partial vegetables, and other strange things, which are to be found on the tops of the highest mountains, and in the bowels of the earth, at a great distance from the sea, and were probably left by the flood †.

All in whose nostrils was the breath of life, of all that was in the dry land, died. And every living substance was destroyed which was upon the face of the ground, both man and cattle, and the creeping things, and the fowl of the heaven; and they were destroyed from the earth; and Noah only remained alive, and they that were with him in the ark.

* Peyrerius, one part of whose pre-adamite system is, that the flood extended no farther than Judea, which he supposes to be all that Moses meant by the earth, would also persuade us, that that writer, by mankind which were to be destroyed, intended the posterity of Adam; by the living creatures, the Gentiles or pre-adamites, mixed with the race of Adam: and, by the great deep, the sea of Palestine.

† This argument is offered with some diffidence; for though the most experienced philosophers now agree, that these shells, &c. are not mock-productions of nature, or originally formed in the places where they are found, by some plastic power of salts, or other minerals (which was the conjecture of Dr. Plot and other naturalists) inasmuch as they are not to be distinguished from

It is now time to consider by what means this terrible devastation was brought on the earth, and in what manner those that escaped it were preserved.

If the deluge were universal, the quantity of water required to effect it is so immense, that it has been generally thought extremely difficult, if not impossible to say, whence it came, or whither it went. The proportion of water, sufficient to cause such an inundation, has been computed at eight oceans; but a person well able to make the calculation says, that there must have been, at the lowest computation, twenty-two oceans. And where to find this, is the question. There are the clouds above, and the deeps below, and in the bowels of the earth; and these are all the stores we have for water*: and Moses directs us to no other for the causes of the deluge. The fountains of the great deep (says he) were broken up, and the win-

real shells, teeth, &c. by the nicest examination of the eye, and even the microscope, and burn not immediately into a calx or lime, as all tophaceous or stony substances do, but first into a coal and then into a calx, which is the known quality of things of a bony or fleshy nature; yet they do not agree that these things were brought in by the universal deluge, for this reason, among several others, that living animals, or fish, have been found in some of those fossil shells, and that such marine substances are sometimes formed and generated in human bodies; and therefore it is supposed they were formed by a spermatic principle, as fish spawn, received into the chinks and other meatus's of the earth, and falling down in rains, &c.; which may be allowed, indeed, of the several kinds of shell-fish, whose shells might preserve them in the earth; but can hardly be admitted as to others of those fossils, such as the glossopetræ, or teeth of the shark, and the other bones of larger creatures. As to the subterraneous woods, and fossil trees, there seems to be no great reason to believe they were thrown down by the deluge, and have lain buried in the earth ever since; it being much more probable, that they either were occasioned by inundations of the sea, or were felled by men in the places where they now lie; as is undeniable of many of them, which still show the marks of the axe.

* Moses, in his account of the creation, speaking of waters above the firmament, though it be generally understood of the clouds and aqueous vapours sustained in the middle region of the air, yet some have fancied them to be waters placed above the heavens, and have been willing to make use of them for a supply, when they could not find enough under the heavens to make up the mass of the deluge; though, if these imaginary waters were there, how to get them down, or to lift them up again, is not easy to tell. But since the system of the world has been better known, and the nature of the heavens, it is presumed there are none that would assert these supercelestial waters, much less make that extravagant use of them, as to bring them down hither for a cause of the deluge.

dows of heaven were opened; and the rain was upon the earth forty days and forty nights. By the great deep some understand the ocean; but others, with more reason, the subterraneous abyss or vast collection of waters in the bowels of the earth*. But it is thought the waters which either the abyss or the rain could afford, will fall prodigiously short of the proportion required. According to the observations made of the quantity of water that falls in rain, the rains could not afford one ocean, nor half an ocean, and would be a very inconsiderable part of what was necessary for a deluge. If it rained forty days and forty nights throughout the whole earth at once, it might be sufficient to lay all the lower grounds under water, but it would signify very little as to the overflowing of the mountains; so that it has been said, that, if the deluge had been made by rains only, there would have needed not forty days, but forty years, to have brought it to pass. And if we suppose the whole atmosphere condensed into water, it would not at all have been sufficient for this effect; for it is pretty certain that it could not have risen above thirty-two feet, which is well known to be the usual height to which water can be raised by the pressure of the atmosphere; since the weight of the whole air, when condensed into water, can be no more than equal to its weight in its natural state, and must become no less than eight hundred times denser; such being the difference between the weight of the heaviest air and that of water. And as to the abyss, if by it we intend the sea, this latter is no higher than the land, as some have formerly imagined, and therefore could contribute nothing to the deluge; it would keep its bed as it does now, and take up the same place; and, if we understand the subterraneous waters, they would be quiet in their cells, and not ascend otherwise than by force; and, if force were used to draw them out on the surface of the earth, their places must be filled again with other waters, so that this turns to no account upon the whole.

This being the case, some cut the knot which they cannot loose,

---

* Notwithstanding the word תהום *tehom*, *depth*, in some passages, is supposed to signify the sea, yet it may be there much better interpreted of subterraneous waters, as it manifestly must in other places. And being here joined with the epithet רבה *rabbah*, *great*, it seems Moses intended that vast collection of waters, which the most sagacious naturalists place in the womb of the earth, the receptacle of the greatest part of that deep which covered the earth at the beginning of the creation.

and shew us the naked arm of Omnipotence; saying, that God created waters on purpose to make the deluge, and then annihilated them again when the deluge was to cease. But our business is not here to enquire what God could work by his almighty power, but to account for this event in the best manner we can from natural causes; nor are we rashly to fly to the divine omnipotence, especially for the creation of new matter. Moses plainly assigns natural causes of the deluge, forty days rain, and the disruption of the abyss; and St. Peter has assigned a cause also, the natural constitution of the world; and neither of them mention a word of a new creation of waters. Others, therefore, instead of a creation, suppose a transelementation, and say the air was changed into water, and that this was the great instrumental cause of the deluge. But such opinion agrees as little with the philosophy of Moses or St. Peter, as the preceding, and renders the opening of the abyss perfectly needless: besides, such a transmutation would in effect be no more than a condensation, the insufficiency of which has been already shown. According to a third expedient, the rain and sea-waters were rarefied so as to reach the determined height: but, if the waters were fifteen times rarer than they naturally are (as in that case they must have been,) it is hard to say how they could either drown man or beast, keep alive the fish, or support the ark. A fourth opinion is, that the antediluvian earth, with all its stones, metals, mineral concretions, and all fossils whatsoever that had obtained any solidity, was totally dissolved in the deluge, the cohesion of its parts perfectly ceasing; that the corpuscles of these solid fossils, together with the corpuscles of those which were not before solid, such as earth, sand, and the like; as also animal bodies, and parts of animals, bones, teeth, shells; vegetables, and parts of vegetables, trees, shrubs, herbs; in short, all bodies whatsoever, which were either in the earth, or that constituted the mass of it, if not quite down to the abyss, yet at least to the greatest depth we ever dig, all these were promiscuously taken up into the waters, and made one common mass; that at length they subsided downwards together, generally; and, as nearly as might be expected in such a confusion, according to the laws of gravity; and thus formed the strata of stone, marble, coal, and the rest, of which the earth manifestly consists. While, in consequence of these being bodies of different kinds and constitutions, which are nearly of the same specific gravity, it thence happened, that

bodies of quite different kinds subsided at the same instant, and fell together with the same stratum; for which reason the shells of cockles, escallops, and the rest, which have a greater degree of gravity, were inclosed and lodged in the strata of stone and marble, and the heavier kinds of terrestrial matter, the lighter shells not sinking down till afterwards, and so falling among the lighter matter, as chalk, and the like. But this strange and bold hypothesis, to which the author was driven, to solve these phænomena of the interior parts of the earth, (which yet might possibly be otherwise accounted for,) is so little consistent with the Mosaic history of the deluge, takes so little notice of the opening the windows of heaven, and is so contrary to the universal law of mutual attraction, and the specific gravities of bodies, accounts for so few of the phænomena of the deluge, implies such a new sort of formation or creation of the earth at the deluge, without warrant for the same, and is so much more than his observations require, or will support, that it cannot engage the assent of any considering person. A fifth opinion is, that though the rains might afford a vast quantity of water towards a deluge, yet the chief cause was the changing the centre of the earth, and setting it nearer to the centre or middle of our continent; whereupon the Atlantic and Pacific oceans must needs press upon the subterraneous abyss; and so, by mediation thereof, force the water upwards, and compel it to run out at those wide mouths and apertures made by the divine power breaking up the fountains of the great deep. These waters, thus poured out from the orifices of the fountains upon the earth, the declivity being changed by the removal of the centre, could not flow down to the sea again, but must needs stagnate upon the earth, and overflow it: and afterwards, the earth returning to its old centre, return also to their former receptacles. This hypothesis gives a fair and easy solution of all the phænomena of the deluge, save only the generality of it, making it topical, and confining it to our continent; for which reason a very sagacious naturalist, who otherwise approves it, proposes a sixth way of solving them; and that is, by supposing, that the divine power might at that time, by the instrumentality of some natural agent, to us at present unknown, so depress the surface of the ocean, as to force the waters of the abyss through the before-mentioned channels and apertures, and so make them a partial and concurrent cause of the deluge. And it appears from instances,

that there are, at some times, in the course of nature, extraordinary pressures on the surface of the sea *, which force the waters outwards upon the shores, to a great height. But this, we fear, is too occult a cause, to give much satisfaction to a philosophic inquirer.

We have still to consider the hypotheses of two other philosophers well known in the republic of letters, we mean Dr. Burnet and Mr. Whiston.

To have a complete idea of that of the former, we must premise that he conceives the first earth, from the manner of its formation, to have been externally regular and uniform, of a smooth and even surface, without mountains, and without a sea; and that the waters belonging to it were wholly inclosed within, or under its upper crust, which formed a stupendous vault around them. This vast collection of waters he takes to have been the great deep, or abyss of Moses; and that the disruption of it was the chief cause of the deluge. For he supposes, that the earth being for some hundreds of years exposed to the continual heat of the sun, which, by reason of the perpendicular position he imagines the earth's axis then had to the plane of the ecliptic, was very intense, and not allayed by that diversity of seasons which now keeps our earth in an equality of temper, its exterior crust was, at length, very much dried; and when the heat had pierced the shell, and reached the waters beneath it, they began to be rarefied, and raised into vapours; which rarefaction made them require more space than they needed before; and, finding themselves pent in by the exterior earth, they pressed with violence against that arch, to make it yield to their dilatation. And as the repeated action of the sun gave force to those inclosed vapours more and more, and made them more strong and violent; so, on the other hand, it weakened more and more the arch of the earth that was to resist them, sucking out the moisture that was the cement of its parts, and parching and chapping it in sundry places; and, there being no winter to close up its parts, it

* We had, upon our coasts, not many years ago, an extraordinary tide, wherein the water rose so high, as to overflow all the sea-banks, drown multitudes of cattle, and fill the lower rooms of the houses of many villages that stood near the sea; so that the inhabitants, to save themselves, were forced to get into their upper rooms and garrets. And how this could be effected, but by an unusual pressure on the superficies of the ocean, our author cannot well conceive.

grew more and more disposed to a dissolution; and, at length, when God's appointed time was come, the whole fabric broke, and the frame of the earth was torn in pieces as by an earthquake; and those great portions, or fragments, into which it was divided, fell down into the abyss, some in one posture and some in another.

This hypothesis, the author thinks, not only agrees with the narration of Moses, and answers the assertion of St. Peter, that the first earth was obnoxious to a deluge from its constitution, but supplies all the defects of other explications. The fall of those prodigious fragments would raise a vast commotion in the abyss, and throw its waves to a great height, which would, for some time, overwhelm the mountains, now first formed, for, after the first violent shock, he imagines there were, occasionally, some secondary ruins, which broke, and made new commotions; till, at length, when all the ruins were settled and fixed, the waters began to settle too, and the dry land to appear. Thus the earth put on a new form, and became divided into sea and land; the greatest part of the abyss constituting our present ocean, and the rest filling up the lower cavities of the earth, mountains and hills appeared on the land, islands in the sea, and rocks upon the shore; and thus Providence, at one stroke, dissolved the old world, and made out of its ruins a new one, which we now inhabit.

But though it be reasonable to believe the first earth had its axis inclined to the plane of the ecliptic, as well as the present, and had the same vicissitudes of seasons; yet, allowing the theorist's supposition, of its parallel position, to be true, it is not conceivable that the heat of the sun would even then, have had the power he imagines, or affect the earth in such a degree as to cause great cracks or fissures in it, or to raise the water under it into vapours, since we find no such effects in the hottest country or season; nor is it probable such rarefaction, were it possible, should be so extreme, as to break through an arch of some hundred miles thick. Besides, it is to be feared, that, if the action of the sun was so strong, the abyss, the only storehouse of waters in the first earth, would have been nearly exhausted † before the time of the deluge. This account, also,

† Dr. Keill has made a plain calculation of this matter, and concludes, that since none of the antediluvian rivers, according to this theorist, returned into the abyss again, it must needs follow, that, in eight hundred and twelve years, it would be quite empty, upon supposition that there were as many rivers in

seems not very consonant to the Mosaic history, which describes a gradual rise and abatement, and long continuance of the flood, not a violent transient shock, which would not have lasted many days, if hours; not to mention the little use our author makes of the rains, which he supposes, indeed, to have fallen throughout the earth, (though he does not know how that could proceed from natural causes) and to have contributed to the disruption of the abyss, by weakening the arch of the earth, and stopping its pores, which would make the vapours struggle the more violently; and that nothing but a miracle could save the ark in so prodigious a storm and convulsion of nature.

The expedient of the other learned theorist is, the trajection of a comet *, which, he supposes, passed so close by the body of the earth, at the time of the deluge, as to involve it in its atmosphere and tail. On which hypothesis, he proceeds to account for the deluge in this manner:

He says, that when the earth had passed through the tail and atmosphere of the comet, which he supposes to consist of vapours rarefied and expanded in different degrees, and in which it would remain, on calculation, for about two hours, it must have acquired a large cylindrical column of vapours, whose basis was somewhat larger than one of the earth's greatest circles, and whose altitude was equal to the diameter of the comet's atmosphere; that these vapours would be impeded from descending towards the sun, by the earth's interposition, and attractive power; and so would fall down, with great violence, on its surface; a great part of which, being in a very rare and expanded condition, after their primary fall,

---

the primitive earth as are in ours; but as there was then twice the land, if there were no seas; so there must be allowed twice as many rivers to water it; and by such a double quantity the abyss would be emptied in half that time.

* That a comet actually appeared at the deluge, is attested by several authors. Pliny mentions one which appeared in the reign of Typhon, that is, at the flood, or immediately before it; and speaks of the direful effects of it. And the above author has endeavoured to prove, that the last most remarkable comet, which was seen in these parts in the year 1680 (whose revolution he computes to be in about 575 years, and whose trajectory Sir Isaac Newton has delineated), was that very comet which came by the earth at the beginning of Noah's deluge, and which was the cause of the same.

would immediately be mounted into the air, and afterwards, on their condensation, descend, in violent and incessant rain, on the face of the earth, and very naturally occasion the forty days and forty nights rain mentioned by Moses.

That the presence of this comet, as it approached and came below the moon, would cause a double tide, as well in the seas above, as in the abyss below; that in the seas would be less considerable, but the other would be vastly great, and produce mighty effects. For on the nearest approach of the comet, the surface of the abyss would put on an elliptic or oval, instead of its former spherical figure; and the orb of earth, which rested on it, would be obliged to accommodate itself to that larger oval surface; which being impossible for it to do while it remained solid, it must of necessity enlarge itself, and by the violent force of the increasing surface of the abyss be stretched, cracked, and have innumerable fissures made quite through it; or rather the tide must open and enlarge those fissures, which were produced at the commencement of the diurnal rotation. Thus would the fountains of the deep be broken up, and sufficient gaps made for a communication between the abyss below, and the surface of the earth above; which was no sooner done, than the fall of the cometic waters began, and quickly covered the earth, and crowded the air with vast quantities thereof; which waters, being adventitious, and of a prodigious weight, must press downwards with a mighty force, and endeavour to sink the orb of earth deeper into the abyss, according as the entire weight of each column of earth, and its incumbent water together, did now require, agreeably to the laws of hydrostatics; which laws he supposes not to have been exactly complied with at the earth's first subsiding into the abyss; otherwise he could scarce have expected any elevation of the subterraneous waters. But since the lowest strata of the earth were, according to him, in a good measure settled and consolidated together, before the upper were all formed, the whole compages would archwise sustain itself much higher than the law of specific gravity would otherwise require; and so upon the disruption of the upper earth, its several columns, as there was room, would settle themselves lower than they were at first; and their weight, augmented by the additional waters of the comet, would squeeze and press on the surface of the abyss; which being a fluid mass, and in-

capable of sustaining a pressure on one part, without equally communicating it to all the rest, must burst out, wherever such pressure was wanting, and throw itself up the fissures, through which it would ascend with a mighty force, and carry up with it whatever was in its way, whether earth or water; and thereby add to the quantity of water already on the face of the earth, and become a fresh augmentation of that deluge which began already to overwhelm and destroy the inhabitants thereof.

The abatement and decrease of the waters of the deluge, our author supposes, was first by a wind, which dried up some; and, secondly, by their descent through those breaches and fissures (at which part of them had ascended) into the bowels of the earth, which received the rest. To which latter also the wind, by hurrying the waters up and down, and so promoting their lighting into the before-mentioned fissures, was very subservient. The air, he grants, could sustain a very inconsiderable quantity in comparison of the intire mass; but as he supposes the antediluvian earth, though it was not destitute of lesser seas and lakes, yet to have had no great ocean, separating one continent from another, and covering so large a portion of it, as the present earth has; he conceives the upper region of the earth, being generally dry and porous, and of a great thickness, was capable of receiving a much greater quantity of water than was on the earth at the time of the deluge.

To this theory objections have been made, as well as to the former: for though there are some surprising co-incidents, which make it indeed probable, that a comet did really come very near, and passed by the earth when the deluge began, and might cause a prodigious tide in the sea, and in the abyss; yet it has been thought somewhat strange, that the swelling of the abyss should have such an effect as to make convenient fissures in the solid crust of earth which inclosed it, without shattering its whole frame. Nor has the theorist's account of draining off the waters from the surface of the earth been judged satisfactory; it being difficult to conceive, that those subterraneous cavities, which he supposes could contain but a small proportion of the waters requisite to make the deluge, should yet be capable of receiving the greatest part of them when it was over. These difficulties, however, might possibly receive a solution; but the greatest objection of all is, that it is far from being clear, whether the atmosphere of a comet be a watery substance or

no; or if it were, that it should afford such a vast quantity of water as the theory has occasion for, on the earth's bare passing through it. For it is said, the observations of the most curious inquirers make it not improbable, that the circle about the body of the comet is nothing but the curling and winding round of the smoke, rising at first to a determinate height from all parts of the comet, and then making off to that part of it which is opposite to the sun. And if this opinion be true, the earth, by passing through the atmosphere of the comet, ran a greater risk of a conflagration than a deluge.

It seems, therefore, after all, that the divine assistance must be called in, on this occasion. For though the waters, which covered the earth at the creation, might be sufficient to cover it again; yet how this should be effected by mere natural means, cannot be conceived. The waters which were suspended in the clouds might, indeed, descend upon the earth, and that in cataracts, or spouts of water (as the Septuagint interpret the windows of heaven), like those in the Indies, where the clouds frequently, instead of dropping, fall with a terrible violence, in a kind of torrent; and this alone might cause a great inundation in the lower grounds: but as the clouds could pour down no more water than they had, which would soon be exhausted at this rate, it seems, from the length of the rain's continuance, that the showers were rather moderate and gradual. The subterraneous stores would afford a much more plentiful supply to complete the deluge, and probably contain more water than enough to drown the world, to a greater height than Moses relates *: the only difficulty is, to draw it out of the abyss on the surface of the earth. And here, since we can assign no natural cause, we apprehend we may, not unphilosophically, resolve it into the divine power,

* Though Sir W. Raleigh allows thirty miles for the height of the mountains, yet the highest in the world will not be found to be above five direct miles in height. Olympus, whose height is so extolled by the poets, does not exceed a mile and an half perpendicular, and about seventy paces. Mount Athos, which is said to cast its shade into the isle of Lemnos (according to Pliny, eighty-seven miles) is not above two miles in height; nor Caucasus much more; nay, the pike of Teneriff, reputed the highest mountain in the world, may be ascended in the three days (according to the proportion of eight furlongs to a day's journey), which makes it about the height of a German mile perpendicular. And the Spaniards affirm, that the Andes, those lofty mountains of Peru, in comparison of which, they say, the Alps are but cottages, may be ascended in four days compass.

which might, on this occasion, so far controul (no greater a miracle than that of continuing) the usual course of nature, as to effect its purpose. And, indeed, the event was so extraordinary, and the consequences thereof so considerable, that it is very reasonable to believe God did, in an especial manner, interpose therein. The Stoics, who supposed alternate destructions of the earth by fire and water, made no doubt of the possibility of a general deluge. "There are vast lakes," says Seneca, "which we do not see; great part of the sea lies hidden and concealed, and many rivers glide in secret; so that there may be causes of a deluge on all sides, when some waters flow in under the earth, others flow round about it, and being long pent up overwhelm it; and as our bodies sometimes dissolve into sweat, so the earth shall melt, and without the help of other causes, shall find in itself what shall drown it; there being in all places, both openly and secretly, both from above, and from beneath, an eruption of waters, ready to overflow and destroy it."

[*Ancient Universal History*, Vol. I.]

CHAP. III.

THE SAME SUBJECT CONTINUED, WITH THE THEORY OF EDWARD KING, ESQ. F. R. S.

After so many conjectures, as have been already formed concerning the cause of the universal deluge, it may perhaps appear both impertinent to attempt a new solution, and also useless, as theories formed on mere hypothesis are always uncertain, and little to be depended upon. But if we give them no more weight than they deserve, and, considering them only as small steps towards the investigation of truth, do not desire any further assent to our conclusions than the probability on which they are founded demands, even such kind of enquiries may be of service, and open a door to new discoveries.

Where we cannot arrive at demonstration, we must be content with probability. Our despair of attaining the one ought not to

make us neglect the other. And with regard to this remarkable event, the universal deluge, every degree of probability, even the smallest, that appears in an attempt to account for it philosophically, has its use; as it tends to remove those objections that are made to the truth of the fact, by persons who may not think the mere relation of it in the Mosaic writings a sufficient proof of the reality of it; or who may be led, from the difficulty there appears in accounting for such an event, to doubt of the authority of those sacred books.

Many ingenious hypotheses have been already formed on this subject; but they all seem liable to most insuperable objections; and therefore I make no scruple to venture another into the world, which appears to me free from such difficulties as they are involved in, and more simple. I am willing, however, it should fall to the ground, as soon as there appear any reasonable and weighty objections to it. I only wish that the hints contained in this paper may be a means of leading some person of greater abilities to a more perfect discovery; and that it may always be remembered, that the fossil shells found in all parts of the earth, are a sufficient proof of the truth of its having been at some time or other entirely covered with water, however fallible any attempt to account for the deluge may be.

Dr. Burnet, in his theory, has given such an account of the deluge, as Dr. Keill has shown to be very improbable and unphilosophical. He has first described the primeval earth so as to divest it of all beauty and elegance, and then has ascribed the deluge to such causes, as are not only somewhat inconsistent with that part of his theory, where he supposes the earth to be well watered and moistened with dew; but are also insufficient to account for the waters flowing over the tops of the mountains; since on the breaking of his imaginary shell, it is impossible to suppose that the waters of the abyss, even on such a concussion, should flow up high enough upon those parts that were left elevated, so as to cover the mountains that now subsist.

Mr. Whiston has called in the assistance of another planetary body; and has supposed the tail of a comet to be so greatly condensed as to afford a quantity of water sufficient for this purpose. But, besides the inconsistency of this theory with that of gravitation, it is no less difficult, according to his hypothesis, to get rid of

the water with which the earth was covered than it is, according to others, to find a sufficient quantity.

Mr. Ray has accounted for this amazing event, by supposing a change to have happened in the centre of gravity of the earth. But how to find a cause for such a change in the centre of gravity, and for a restoration of it to the same place again, is more difficult, and the supposition of it more inconsistent with our philosophical ideas, than any other hypothesis whatever.

Such have been some of the principal theories hitherto advanced, and far be it from me to presume that mine may not in the end be found equally fallible; but it appears to me at present to be more plain and consistent, and at the same time is free from that great difficulty which has perplexed all the rest, and is indeed the most important difficulty in the enquiry, that is, the accounting for a sufficient quantity of water.

We find in the Mosaic history of the creation, that God at the first created sea as well as land; and therefore have grounds to believe both from thence, and from the reason of things, that there was as great a quantity of sea on the antediluvian earth, as there is now upon the earth in its present state.

We find also the whole surface of the earth to be undermined by subterraneous fires, which make their appearance in various places, in very formidable volcanoes. This has been the case in Italy, and amongst the Azores, in Tartary, in Kamtschatca, in South America, in Ireland, in the islands of the East Indies, and in other parts; and we have reason to believe that these subterraneous fires have made eruptions, not unfrequently, even in the bottom of the sea; as Mr. Mitchell has made appear in his excellent paper concerning the causes of earthquakes.*

We have also, in the Philosophical Transactions, an account of entire islands being raised in the Archipelago, and likewise amongst the Azores, by such subterraneous fires†; and Mr. Ray, in his Travels, mentions a mountain one hundred feet high, raised by the earthquake in 1538, which also threw up so much earth, stones, and ashes, as quite filled up the Lacus Lucrinus‡.

---

* Philos. Trans. Vol. LI. Part II. p. 566.

† Philos. Trans. No. 372, or Eames's Abr. Vol. VI. Part II. p. 203, and Jones's Abr. Vol. V. Part II. p. 196.

‡ Ray's Travels, old edition, p. 273.

To which may be added, that fossil shells and other marine bodies are so universally found in all parts of the present continents and islands, as to amount almost to a demonstration, that all the now dry land was once covered with sea, and that for a considerable space of time, probably much longer than the continuance of the deluge is related to have been. For though such a violent flux of waters might have thrown up some shells and marine bodies upon the hills and mountains, yet it could not have flung up such vast quantities, nor so universally. The prodigious beds of shells which we now find in all parts cannot well be accounted for, but by supposing the waters, in which those shell-fish lived, to have covered the countries where they are now found, for a long time, and even for ages.

The supposition, therefore, which I am about to advance, founded on these facts, is this: that originally Almighty God created this earth with sea and land nearly in the same proportion as they now remain, and that it continued in that state for many ages, during which the bottom of the sea became covered with shells, and various heterogeneous bodies; that from the first of its creation there were also many subterraneous fires found within the bowels of the earth; and that, at the appointed time, these fires bursting forth at once with great violence, under the sea *, raised up the bottom of the ocean, so as to pour out the waters over the face of what was before dry land, which by that means became sea, and has perhaps continued so ever since, as that which was before the flood the bottom of the sea, probably from that time has continued to be continent and dry land †.

* Mr. Mitchell has shewn, in his paper on the causes of earthquakes, that such subterraneous fires are at all times very liable to make eruptions under the sea, and that when they do so, the earthquakes consequent upon such eruptions are more extensive than any whatever.

† I do not mean by this to insinuate that all that part of the globe which is now sea was dry land before the flood; or that the antediluvian ocean was merely of the extent of our present continent. I apprehend, on the contrary, that there was always a greater proportion of water on the face of the earth than of continent; and I would only be understood to mean, that all that which was dry land before the flood is now buried under the sea, whilst that which was a part of the bottom of the antediluvian ocean forms our present land; and that consequently some part of the ocean was sea both in the antediluvian earth and in the present state of it, and common to both.

This hypothesis may perhaps be liable to great objections; but it is at least consistent with what Moses relates of the fountains of the great deep being broken up; and, without any perplexity or difficulty, accounts at once for a sufficient quantity of water to cover the tops of the highest antediluvian mountains, even supposing they were left standing; though it is not improbable that they might be thrown down by means of the same earthquake. If they were left standing, some of them might (on the retreat of the waters from their tops after the first concussion) form some of the islands that now subsist.

I must also add, that this hypothesis is perfectly consistent with, and perhaps in some measure accounts for, that singular position of the strata of coals, ores, and various kinds of earths (mentioned in Mr. Mitchell's paper), which are found always sloping from mountainous countries, and higher grounds, towards the bottom of the sea; so that what is nearest the surface of the earth in mountains and high countries lies deepest in low lands and under the sea.

It is, besides, somewhat confirmed by that singular observation of Dr. Hasselquist's, in his travels, p. 33, where, speaking of Natolia and the eastern countries in general, he says, "In no place was it more evident that the continent we call earth, was in the beginning the bottom of the sea." Ulloa also informs us, that the same thing is evident in the whole country of Valles in South America *: and Norden tells us, that the rocks in Egypt bear evident marks of having been washed by the sea †.

These are the reasons which induce me to venture upon this supposition; and now I will just consider one or two objections, that appear to me amongst the most material which may be made to what I have advanced.

It may perhaps be said, that we read ‡ "of the waters returning from off the earth, and of their being abated at the end of the hundred and fifty days: and also of the waters decreasing continually till the tenth month; and of the tops of the mountains being then seen." And it may be objected, that we ought from thence to conclude, that the waters of the deluge, having covered what was before

* Ulloa's Voyage to South America, Vol. II. p. 99.
† Norden's Travels, Vol. II. p. 21.
‡ Genesis, ch. viij. 3—5.

dry ground, afterwards retreated, and left the very same hills and land dry again.

But this conclusion is by no means necessary; for all that can be inferred from what we find in Genesis concerning the decrease of the waters, is, that they gradually subsided from off the face of what is now continent and dry land, as of course they would do on the elevation of it, agreeable to the foregoing hypothesis. And indeed, if the deluge was effected in the way here supposed, we can then give a rational and easy account how all the water came to drain off the the ground, and to leave it dry so soon as is recorded: which otherwise is a circumstance in this piece of history very perplexing. It is evident, that such a violent earthquake, or bursting forth of the subterraneous fire, as is here supposed to have raised the bottom of the then sea (the present continents) at once as high or higher than what was before dry land, must in a very short time have drowned and overwhelmed the antediluvian earth, by pouring out the waters upon it; and it is also evident, that for some time the bottom of the sea, so raised, would continue covered with the waters, which, till the vast agitation into which they were flung subsided, would continue flowing backwards and forwards. But, by degrees, and very easily within the time mentioned in Scripture, the water would drain off from all the higher parts, and leave the new land quite dry, and in the state we now find it, with strata of shells, and sand, and stones, and other bodies, lying just as the sea had by accident many ages before placed them. Whereas, were the deluge occasioned only by an addition of water sufficient to raise the surface of the sea higher than the land and mountains, in that case, it is impossible to imagine any means, at all consistent with the course and laws of nature, by which such an immense body of water could be evaporated or conveyed away in so short a space of time. And besides, in that case, the shells, &c. flung upon the land by the concussion of the waters, and subsiding there within so short a space of time, would rather be found lying according to their specific gravities: a fact which Dr. Woodward supposed certain, but which is by no means true. Nor indeed, according to the conjectures here advanced, is it at all necessary that it should be so. For, as I imagine the shells and other marine bodies, which are now found on various parts of the dry land, to have been placed there gradually during a succession of ages, whilst it was the bottom of the sea; it will follow, that they must

be found just as the sea, by its washings and motion, laid them: which would of course first wash many of them together, and then wash gravel, or sand, or clay, or other substances over them; after which, more shells or other bodies would be deposited, and then more stones or gravel, &c. according to the nature of the soil. In short, whatever was specifically heavier than water, would (after its removal by any agitation) soon subside, and remain fixed, whether the substances underneath it were specifically heavier than itself or no: it is sufficient that they were but all specifically heavier than the water.

We find to this day great changes are continually making, within the memory of man, both on the face of the earth, in the shores, and in the bottom of the sea, even in those small parts of it that we are acquainted with; and such changes must also have happened before the flood, and might very probably produce that situation of shells, &c. so different from what might be expected from their specific weights.

Another objection may perhaps be made by saying, if all the antediluvian earth was at once overwhelmed, and of course all its plants with it, whence came it to pass, that the now dry land was so soon covered with vegetables and herbage of all kinds? To this I answer, in the first place, that the difficulty is just the same, whether we suppose the bottom of the antediluvian sea to be the present continents, or whether we suppose the face of the earth to have remained the very same; since, by the waters of the deluge, all plants, trees, and vegetables, must in both cases equally have been destroyed; and nothing could well remain, except some of their shoots and seeds; which might just as well take root on the new continent, on the subsiding of the waters, as on the old. And in the next place, I answer, that there are not a few instances (as is shown in Stillingfleet's Tracts*) of barren rocks and plains becoming by degrees well covered with verdure, though very remote from any places that might apparently furnish seeds. They have first borne a kind of moss, and afterwards other plants of an higher order (the seeds being brought there by accident, and by the various and admirable means of conveyance, which the Creator has given them), till at last

* Stillingfleet's Tracts, p. 78, and also p. 45, where an instance is produced much to the purpose, of marshes becoming by degrees fine meadows.

they have been covered with rich verdure. To which may be added a very extraordinary fact, now well known, namely, that if a piece of ground which has not been cultivated be turned up, and the clods loosened, it will very soon produce a variety of plants, some of which were never known to grow there before. We find that one acorn is sufficient to produce a forest, and it is by no means to be supposed (let the deluge have happened how it would) that, immediately after it, the earth was as well clothed with verdure, as it has become since. Probably it was for a time in general very barren, except such parts as Noah and his sons cultivated, with seeds which they had preserved in the ark.

As to the leaf which the dove brought in *, that might be found on some plant which had taken fresh root immediately on the subsiding of the waters, or it is not impossible but the top of some antediluvian mountain, having been but slightly covered, might on the ceasing of the first concussion (as I before observed) remain in the state of an island, elevated above the surface of the sea.

I apprehend, no objection of any weight can arise from the description of paradise in Scripture, nor from its being said that the ark rested on the mountains of Ararat: since, whether the continent was changed or no, there is no place now remaining that answers the description of the former; nor is there any thing said about the latter that should lead us to conclude there ever was such a mountain as Ararat before the flood.

But, leaving these objections from the words of Scripture, and the history of the deluge; another may perhaps arise, from this circumstance, that shells are found in various parts of the earth, which are evidently not the shells peculiar to the seas adjoining, but such as belong to a different climate. This fact at first certainly seems to contradict what I have advanced: and yet, when well considered, it will perhaps rather be found to confirm my hypothesis. For let any one but look on a terrestrial globe, and he will instantly see, that the present continents are evidently not in the same climates as the present seas; and therefore, though the shells found in many places of the earth are not found in the neighbouring parts of the ocean; yet, when those parts of the earth were ocean, they might have had a very proper climate and situation there. Thus, for in-

* Genesis, viii. 11.

stance, we may observe that the Mediterranean is in a more southern climate than the neighbouring continent of Europe, and in a more northern climate than that of Africa. And the whole continent of Asia is in a climate much more northern, than the neighbouring Indian ocean.

But, if this solution of the difficulty is not thought sufficient, it may be added, that so great a concussion, and such a change in the figure of the earth, as must have happened from the subterraneous fires elevating so many parts higher than they were before, might possibly affect the gravitation of the parts of the globe of the earth, and cause it to revolve round a different axis after the flood; whence there would undoubtedly arise a change of climate in all parts, sufficient to account for the present situation of shells, in places so foreign to the climates where shell-fish of the same species are now found. And as I have before observed with regard to seeds, so it may also be observed with regard to shell fish, that the conveyance of a very few of each sort (by the flux of water) to the beds proper for them, would be sufficient to preserve all the various kinds, and to cause them now to be found in such numbers, in those parts of the ocean that are best adapted to each peculiar class.

Another thing proper to be taken notice of, is the horns and bones of terrestrial animals being found in the earth, together with fossil shells; which seems to contradict the supposition of the present continents having been originally the bottom of the sea. But with regard to this, I must beg leave to observe, that probably some of those bones have been deposited there since the flood, and have been covered by an addition of earth, as has happened also to some of the trees and woods that were cut down in this island by the Romans. And, as to the rest, it cannot be supposed, but that on the first great eruption, which poured the waters of the ocean upon the dry land, there must have been a violent agitation for some time, by their flowing backward and forward; during which interval, the bodies of many terrestrial animals (floating on the water) would be washed to different parts of the new-raised continent, and be left there as the water subsided.

Some little objection perhaps may arise, from its being observed that the sea at present covers a much greater part of the globe than the dry land does.

But I apprehend this was also the case before the flood; and it

may easily be conceived, that some part of the bottom of the antediluvian ocean might be flung in the manner supposed in this paper, and not the whole; and that the bottom of the present ocean consists not only of what was before the flood dry land, but also of some part of what was, even from the beginning, the bottom of the sea.

I will therefore only just add, that probably the same subterraneous fires (which originally raised the continents and islands that now appear, and have ever since been making great changes in the bowels of the earth, and producing those tremendous earthquakes, which have happened from time to time) may in the end break forth with redoubled violence, and destroy it, in the manner foretold in Scripture.

It may not be amiss to add, in confirmation of the foregoing hypothesis, that the beds of shells, discovered in chalk-pits, gravel-pits, and other places, consist generally of one or two, or at most of a very few different sorts in each particular place, as they would of course do upon a supposition that those respective beds were formerly at the bottom of the sea, in the several places where those different kind of shell-fish lived and bred; and that they were from thence, together with the bottom of the antediluvian ocean, raised up by the force of subterranean fires: for we may observe in the present seas, that one species of shell-fish take up their habitation in one place, whilst those of a different species are found in some other; and that numbers of the same kind, as for instance cockles, or oysters, are generally found on the same banks. The present appearance of fossil shells, therefore, does at least in this respect seem consistent with the conjectures here advanced: whereas, upon a supposition that these fossil shells were carried to their respective places, at the time of the flood, merely by the torrent of water that then flowed to and fro, they ought rather to be found mixed promiscuously together; and not those of one species in one place; and those of a different species in another. And I beg leave here to mention, that, since the writing of the foregoing paper, I find an hypothesis somewhat similar to what is here advanced was adopted by Lazzaro Moro, a Venetian author, who asserts that the continents were originally raised by subterranean fires; but he considers this merely as the cause of their first and original formation, and not as having occasioned the deluge, nor as having happened at that time. [*Phil. Trans.* Vol. LVII.]

CHAP. IV.

ON THE CAUSE AND NATURE OF THE INEQUALITIES THAT DIVERSIFY THE SURFACE OF THE EARTH.

In a Letter addressed to Sir HUMPHRY DAVY, by WILLIAM RICHARDSON, D. D.

SIR,

I REQUEST you will be so good as to lay before the Royal Society the following Observations on the Natural History of that part of Antrim, (contiguous to the Giant's Causeway,) which you and I examined so carefully together. I know not any country that deserves so well to have its facts faithfully recorded; from the important conclusions to which they lead.

The basaltic area (taken in its whole extent) comprehends the greater part of Antrim, and the east side of Derry, to a considerable depth.

In a geological point of view, Nature * has been very kind to this district; for not content with assembling together in a small space so many of her curious productions, and arranging them with more regularity and steadiness than in any other country described, she has condescended occasionally to withdraw the veil, and lay herself open to view, often exhibiting a spectacle equally gratifying to the admirer of magnificence, and to the curious naturalist, who can here by simple inspection, trace the arrangements which are to be discovered elsewhere, only by penetrating beneath the surface of the earth.

As soon as we enter the basaltic area, we begin to perceive traces of these arrangements; as we advance farther north, they increase; and in the tract near the shore, and especially at the island of *Rathlin*, which seems to have come fresher from the hand of Nature than the rest of our area; the stratification of the whole is perfectly

---

* By the word nature, which frequently occurs in the course of this Memoir, I always mean, according to RAY's definition, the wisdom of God in the creation of the world.

visible, and the nature of the several strata laid open to us at their abrupt and precipitous terminations.

To the southward we perceive the distinctive features abate, and wear away; the basaltic stratification indeed remains, but is no longer displayed to us in the same manner; the neat, prismatic, internal construction, of the strata, which occurs so frequently on, and near, the coast, is scarcely to be met with at a distance from it; a rude columnar appearance is all we find, and that but rarely.

It is at the periphery of our area, and especially at its northern side, that every thing is displayed to the greatest advantage; here we have perpendicular façades often continuous for miles, and every separate stratum completely open to examination.

Of these façades, four are more distinguished by their grandeur and beauty than the rest, Magilligan Rock, Cave Hill, Bengore, and Fairhead.

The two former are at the extreme points of the north-west diagonal of our area, and nearly forty miles asunder; they are at the summits of mountains, and accessible by land.

The precipitous faces of Fairhead and Bengore, to which I had the pleasure of attending you, and which are visible only from the sea, are the most beautiful, and the most curious; for the strata, which at Magilligan and Cave Hill, are all nearly similar, at Fairhead and Bengore are much diversified. Of Fairhead I have already published an account in Nicholson's Journal, for December 1801, and I now propose to execute an intention which I have had for some years of giving a minute account of Bengore.

I am aware that it will be extremely difficult to convey a clear and adequate idea of an assemblage of 16 strata, (for such is the number of which our promontory is composed), appearing and disappearing at various altitudes, yet retaining each its own proper place, and forming together a most beautiful and regular whole, though never considered as such before.

But as I have the aid of very correct views of the most important parts of the façade, to the accuracy and fidelity of which I have already obtained your testimony—I shall venture to proceed, for I am anxious to bring into notice the most complete exposure of the internal structure of a district, that I have seen or read of; as there is little likelihood that any other person will enjoy the

opportunities which I have had for so many years, of exploring this interesting part of our coast, through a turbulent sea and rapid tides.

Description of the Promontory of Bengore, and its Stratification.

This promontory commences at the termination of Bushfoot Strand, where the coast, the general direction of which for several miles had been due east and west, turns to the north-east, and after being cut into several semi-circular bays, deflects to the S. S. E. and near the old castle of Dunseverick, resumes its former rectilineal and nearly eastern direction.

The promontory occupies the interval between Dunseverick, and the Black Rock, at the end of Bushfoot Strand, about four English miles; the façades commence at Black Rock, and increase in height until we reach Pleskin, where the perpendicular part at the summit is 170 feet, and the precipitous part from the bottom of the pillars to the sea 200. As we proceed on from Pleskin to Dunseverick, the height gradually abates, and is finally reduced to about 100 feet.

In this whole space, wherever the precipice is accurately perpendicular, the several strata are easily distinguished from each other, but where the slightest obliquity prevails, a grassy covering is formed that effectually conceals all beneath it; hence the face of the precipice seems much diversified; the columnar strata in some places only exhibiting detached groups of pillars, while in others they form extensive colonnades.

I shall now state the appearances as we approach, and coast the promontory from the westward, noticing in this first view of the precipice, every thing that may be considered as general, and reserving for my return in the contrary direction, a detailed account of the strata taken separately.

The first circumstance, that occurs to the attentive observer on his approach, is, that, although both the promontory itself, and the strata composing it, ascend to the northward, yet it is not in the same angle, the strata being more inclined to the horizon than the line tracing the surface of the promontory, a fact which I shall account for afterwards.

From the Black Rock to the Giant's Causeway (about a mile)

the materials, and their arrangement, are similar to those of the coast to the westward, viz. strata of table basalt, generally separated by thinner strata of a reddish substance.

At the Giant's Causeway a new arrangement commences, by the aggregate of which our coast is formed; nature having changed her materials, or their disposition, or both, every two or three miles. To the system of strata comprehended between the Giant's Causeway and Dunseverick I now limit myself, as all the strata composing it emerge between these two points.

As we proceed along the coast from the Giant's Causeway eastward, we perceive the whole mass of strata ascend gradually, culminate at the northern point of the promontory, and then descend more rapidly, as the land falls away to the south-east, until having traced them across the face of the precipice we see them immerge separately at and beyond Portmoon Whyn Dykes.

The western side of the promontory is cut down perpendicularly, by eleven Whyn Dykes; the intervals between them are unequal, but they all reach from the top of the precipice to the water, out of which some of them again emerge in considerable fragments; they are all constructed of horizontal prisms, which are strongly contrasted with the vertical pillars of the strata through which they pass.

One of the dykes at Port Cooan, on Bengore, half a mile from the Giant's Causeway, is very beautiful; an insulated rock about 160 feet high, and 20 in diameter, stands perpendicular in the middle of a small bay; the main body of the rock is similar to the contiguous consolidated masses; but on the east side a singular whyn dyke is joined to it, composed, (as they often are) of several walls agglutinated together, with wall-like fragments of other parts of the dyke emerging at their base; the solid mass of dyke is seen cutting down the precipice to the southward at 150 yards distance.

Depressions of the Strata.

Soon after we have passed the last of our whyn dykes at Port Spagna, (a name derived from a vessel belonging to the Spanish Armada having been driven ashore in that Creek), we discover a new and curious circumstance, viz. that the western half of the promontory has sunk or subsided between thirty and forty feet,

without the slightest concussion or derangement of the parallelism of the strata.

Two other depressions appear as we proceed onwards, one at Portmoon, and the other at the angle where the promontory begins to project from the rectilineal coast; these however are far less considerable in thickness than the preceding, neither of them exceeding five feet.

Such depressions occur at the collieries near Ballycastle, and generally on one side of a whyn dyke. We have also at Seaport, two miles west from the Giant's Causeway, a dyke, oblique and undulating, with a depression of the strata of about four feet on one side: but on Bengore promontory our dykes are unaccompanied by depressions of the strata; and where we have depressions, we do not find a trace of a dyke.

The portions of this extensive façade, which I have selected for explanatory views, are Portmoon, in or near which most of the strata emerge, and Pleskin, where the strata culminate. Each of these views too, exhibits one of our depressions; but in that of Pleskin, the first apparent depression is purely an optical effect arising from the position of my friend Major O'Neal, of the 56th, who took his view from the water.

Enumeration of the sixteen Strata that compose the Promontory of Bengore, taken in their regular Order, and counting from above.

The country immediately to the southward of Bengore is, like the Promontory itself, a stratified mass, accumulated to the summits of Craig Park and Croaghmore, the first five hundred and the second seven hundred feet high; but with these strata I have nothing to do, limiting myself to those alone of which the promontory is formed, and which are exhibited in its façades.

The uppermost of these commences near half a mile to the eastward of the angle, where the coast, deflecting from its due east and west course, turns to the north-west, and begins to form the promontory.

So far the course of this stratum is to appearance perfectly horizontal; for the strata all ascending to the north, the intersection of their planes with the plane of the sea, must run east and west, that is, in the present case it coincides with the direction of the coast.

But when the coast changes its direction, this coincidence ceases, and the façade (that is the vertical section of the coast) losing its east and west course, its strata must appear to ascend towards the point it turns to; therefore the strata at Portmoon, and along the north-east side of the promontory, should ascend obliquely along the façades, as they actually do.

First Stratum.

The stratum I commence with forms the whole façade, from its first appearance until it reaches the promontory; it consists of massive pillars rather rude, and about sixty feet long, its course for half a mile (as I have stated) seems horizontal; but on the face of the promontory it ascends, and continues to rise uniformly until it reaches the summit, which it lines as far as Portmoon, on the south side of which it loses some of its thickness, then suddenly disappears and vanishes from that façade, receding westward in the form of a stony ridge, and is seen no more.

Second Stratum.

The stratum upon which the preceding rests, is red as brick, and about nine feet thick; it appears in spots, and patches just above high water mark, so long as the incumbent stratum continues horizontal; but when that rises obliquely, the second ascends with it; it is now completely displayed, and having supported the preceding in its course to the summit, vanishes with it and is seen no more

These ochreous matters, so common in all basaltic countries, according to Mr. F. St. Fond's opinion, were once pure basalt, but have undergone some chemical process of nature we are unacquainted with, by which their colour has been changed.

Third Stratum.

The next stratum is the last of those composing the promontory which appears beyond it; for so long as the first and second continue their horizontal course towards Bengore, this third accompanies them, shewing its upper surface between high and low water mark; but when it ascends along with the others across the façades, it displays its whole thickness, above fifty feet.

This stratum is of that variety of basalt, I have on different occa-

sions distinguished by the name irregular prismatic: it resembles the columnar basalt in grain, but differs from it totally in principle of internal construction; for its prisms are small, not articulated, and indifferent as to the position of their axes, which is perpetually changing.

The irregular prismatic basalt accompanies the columnar in most countries, as at Pont du Baume, at Trezza, at Bolsena in the Sound of Mull, and at Staffa. In Antrim, it is very common; and here is a striking resemblance between the rock crowning the celebrated columns at Staffa, and a stratum covering a very neat colonnade at Craigahullur, near Portrush.

This stratum is scolloped off irregularly from the point where it becomes superficial, until it completely disappears; a thin stripe of its lower edge alone is ever resumed again.

Fourth Stratum.

The next three strata will require only very short descriptions. The fourth is about seven feet thick, entirely columnar, the pillars small, but not neat; they appear very white from a thick covering of Byssus saxatilis, which shews a great predilection for this stratum.

Fifth Stratum.

This stratum is ochreous, and more of a slate colour than any of the other red strata; as it is friable, it soon acquires a grassy coat, through which it is only in spots that it shews its proper colour; it is about eight feet thick.

Sixth Stratum.

This stratum is composed of rude massive pillars so coarsely formed, that on the least abatement of perpendicularity the columnar form can scarcely be traced. This stratum is about ten feet thick: it forms the vertex of the beautiful conical island Beanyn Daana.

These last strata, though they have nothing very remarkable in themselves, nor contribute much to the beauty of the façade, yet exhibit one of the most important facts I am acquainted with in natural history, and which, when attentively considered, throws

much light on the nature of the operations performed upon our globe since its consolidation, and leads us irresistibly to conclusions extraordinary and unexpected.

The fourth, fifth, and sixth strata reach the top of the precipice, and vanish together at the waterfall in the north-west corner of Portmoon. When they come to the surface, they turn inland to the westward in long stony ridges; these obstruct the course of the waters in their descent along the inclined plane, formed by the surface of the promontory, and throw them over the precipice, in a cascade highly beautiful after rain.

On the façades to the north-west not a trace of them appears, these being entirely formed by the lower strata, which I have not yet noticed; but at the distance of a mile, at the great depression (already mentioned), the fourth, fifth, and sixth strata, with a narrow stripe of the third, suddenly appear, in their regular posts, their proper order, and with all the characteristic marks peculiar to each separate stratum.

In the interval between the depression at Pleskin, and the Giant's Causeway (about a mile), these three strata often appear in a desultory way on the summit of the precipice, wherever it is of sufficient height to receive them, always preserving their usual thickness, their characters, and their order; so that a person master of the order I am detailing, as he approaches a rising point of the precipice, can tell its strata, and their order, before he is near enough to distinguish them.

Seventh Stratum.

The rude and massive pillars of the sixth stratum pass into the neater, and much longer columns of the seventh, without interrupting the solidity or continuity of the material; exactly as a down-held hand appears to separate into fingers. The thickness of this stratum, that is the length of the pillars of which it is formed, is fifty-four feet; and in its passage across the face of the precipice, displays more beautiful colonnades than any of the others.

This seventh stratum emerges from the beach immediately behind the south-east point of Portmoon, and where it first shews itself in that bay, has its lower edge raised only a few feet above the water; it forms the upper frustum of the larger of the two conical islands,

ascends obliquely along the face of Portmoon, and continues to rise until it composes the upper range in the beautiful façade, properly called Bengore Head. This is probably the most magnificent of all, its convexity towards the sea producing a fine effect. The lower edge of this stratum, that is the line forming the base of its pillars, has here, as at Pleskin, attained the height of three hundred feet above the water.

This seventh stratum, like those above it, also suffers an interruption; for after having exhibited itself to such great advantage at Bengore, the extreme northern point of the promontory lowers, and this stratum disappears for about one-third of a mile; as the promontory rises, it is resumed again in great beauty at Pleskin, and is interrupted no more; we scarcely ever lose sight of it until we reach Port Noffer (the next bay to the Causeway); here, for want of perpendicularity it is little seen, and is finally lost over the Causeway, we know not well how.

Eighth Stratum.

The next stratum is of the same variety of basalt with the third, that is, irregular prismatic; it is fifty-four feet thick. Where it emerges at the south-east corner of Portmoon, it is quite accessible by land, and affords the best opportunity I know for examining this species of basalt, as it is there very neat.

There is little more of this stratum seen in the façade of Portmoon for want of perpendicularity, but it forms the lower frustum of the great conical island Beanyn Daana, and the whole of the smaller, except the base; it is well displayed over the remainder of the precipice, it forms the intermediate stratum between the magnificent colonnades at both Bengore and Pleskin, and finally is lost just over the Giant's Causeway. Large globular fragments have fallen from it, and are scattered about the Causeway.

Ninth Stratum.

This stratum is forty-four feet thick, that being the exact length of the neat pillars composing it; at its emersion it forms the bases of the two conical islands in Portmoon, and is no more seen in that bay; but immediately to the northward it begins to shew itself in colonnades and groups, some of them resembling castles and towers.

It ascends along the precipice obliquely, like those above it, forms the lower range at Bengore and Pleskin, from which last it dips to the westward regularly, composes the group at Port Noffer, called the Organs; seen from the Causeway, and finally at its immersion, or intersection with the plane of the sea, it forms the beautiful assemblage of neat pillars, so long distinguished by the name of the Giant's Causeway.

At these two intersections, each of them accessible by land and water, the prisms exactly resemble each other in grain, size, and neatness; the interval between them is full two miles, through great part of which this stratum is displayed at different heights; it culminates between Pleskin and Bengore, with its lower edge more than two hundred feet above the water.

We see now what a diminutive portion of our vast basaltic mass has, until lately, monopolised the attention of the curious; and even after it was discovered that we had many other, and much finer collections of pillars on the same promontory, it never occurred, to those who were preparing to give accounts of them to the public, to examine whether these were mere desultory groups, or detached parts of a grand and regular whole, which a more comprehensive view of the subject would soon have laid open to them.

Tenth Stratum.

The stratum upon which the pillars of the preceding rest, is ochreous, red as minium, and about twenty feet thick; it is scarcely seen at Portmoon, a patch alone of its surface being distinguishable under water at low tide; but immediately to the northward it shews itself, and from its bright colour makes a conspicuous figure across the face of the precipice in a course of more than a mile and half; its last appearance to the westward is at Rovinvalley, the opposite point of the bay from the Giant's Causeway, from which we have a good view of it. The final dip and immersion of this tenth stratum, as well as its emersion, are lost for want of perpendicularity.

The six remaining strata are all similar in material, but differing much from each other in thickness; they are all of that description called tabular basalt, sometimes shewing a faint disposition to assume a columnar form at their edges, and always separated from each other by ochreous layers.

These six strata are not so perfectly distinct as those above them,

for sometimes we think we can count seven, and again not more than five; nor does each of these preserve the same thickness through their whole extent, for they are deeper towards the northern point, where they culminate, forming by themselves a perpendicular façade near two hundred feet high, but they grow thinner as they recede from this centre.

The jets of black rock to which they give rise, make their last appearance on the west side at Rovinvalley, where they strongly display the inclination of their strata, (the same with all the rest) to those approaching from the westward; their final immersion is lost for want of perpendicularity.

I shall now proceed to select from the great mass of facts that are exhibited on the face of Bengore promontory, and occur in the contiguous basaltic country, such as seem applicable to geological questions, and likely to throw light on such subjects.

Facts applicable to geological Questions.

1. Every stratum preserves accurately, or very nearly, the same thickness through its whole extent, with very few exceptions.

2. The upper and lower surface of each stratum preserve an exact parallelism, so long as they are covered by another stratum; but when any stratum becomes the superficial one, its upper surface is scolloped, or sloped away irregularly, while the plane forming its base continues steady, and rectilineal; but the parallelism of its planes is resumed as soon as another stratum is placed over it.

3. The superficial lines bounding the summit of our façades, and our surface itself, are unconnected with, and unaffected by, the arrangement of the strata below them.

4. Nature, in the formation of her arrangements, has never acted upon an extensive scale in our basaltic area, (at least on its northern side, where our continuous precipices enable us to determine the point with precision,) but changes her materials, or her arrangement, or both, every two or three miles, and often at much smaller intervals.

5. Wherever there is a change of material, as from one stratum to another in a vertical line; or where the change is in a horizontal direction by the introduction of a new system; or where a whyn dyke cuts through an accumulation of strata; in all these cases the change is always *per saltum* and never *per gradus*, the lines of de-

marcation always distinct, and well defined; yet the different materials pass into each other without interrupting the solidity and continuity of the whole mass.

6. The façades on our coast are formed as it were by vertical planes, cutting down, occasionally, the accumulations of our strata; the upper part of these façades is generally perpendicular, the lower steep and precipitous.

7. The bases of our precipices commonly extend a considerable way into the sea; between the water and the foot of the precipice, (and especially near the latter) there is frequently exhibited the wildest and most irregular scene of confusion, by careless observers supposed to be formed by the ruins of the precipice above, which have fallen down; such, no doubt, was Mr. Whitehurst's idea, when he describes one of these scenes as "an awful wreck of the terraqueous globe."

But a more attentive observer will soon discover that these capricious irregularities, whether in the form of rude cones, as at Beanyn Daana, and the west side of Pleskin; or towers, as at the dyke of Port Cooan and Castro Levit, at the foot of Magilligan façade, even spires and obelisks, as to the westward of Kenbaan, and at the Bull of Rathlin; yet all of these once formed part of the original mass of coast, stratified like it, and their strata still correspond in material and inclination with those in the contiguous precipice.

8. These vertical sections or abruptions of our strata are by no means confined to the steeps that line our coast; the remaining boundary of our basaltic area has several of them equally grand; and similar abruptions, or sections (though not so deep) are scattered over a great part of our area, and especially on the ridges of our hills and mountains which are cut down in many places like a stair, by the sudden abruption of the basaltic stratum.

9. Wherever the strata are thus suddenly cut off, whether it be a mass of accumulated strata as in the façades on our coast, or solitary strata in the interior; the materials on one side of the abruption are completely carried away, without a fragment being left behind, while on its other side the untouched stratum remains intire and undisturbed.

I shall not proceed to apply these facts to support, or invalidate, any of the numerous theories which have given rise to so much

controversy, in which I myself (as you know) have borne some part; I shall look to nature alone, without much reference to opinions, and shall endeavour to trace, by the marks she has left behind her, some of the grand operations she once executed on the surface of our globe.

Varro divided the time elapsed since the beginning of the world into three portions, which he distinguished by the names, *prolepticum*, *fabulosum*, and *historicum*.

The first comprehended the period of absolute darkness; in the second some faint lights were thrown upon the history of its events, by fable and tradition; in the third, the historian had the common aids from which history is usually compiled.

The natural history of the world seems to admit of a corresponding division. In the first I include the formation of our strata, their induration, their derangement from the horizontal position in which they seem originally to have been placed, and the operation of cutting them down by so many whyn dykes.

In the second division, corresponding to Varro's *fabulosum*, I comprehend the operations performed upon our globe, posterior to its final consolidation, and antecedent to all history or tradition; operations therefore that can be established by the visible effects alone which still exist, written in strong characters.

The third division contains the period since we acquired some knowledge of natural history, became acquainted with causes and able to trace the connection between them.

With the operations performed in the first division (corresponding with Varro's *prolepticum*) modern theorists assume that they are well acquainted, able to account for every appearance, and to detail the whole process of original formation. I however shall decline noticing these early processes of nature, and limit myself to the second division of natural history, hoping from the prominent features of my country that remain still undefaced, and from its curious facts, to trace and demonstrate the great effects that have been produced upon our surface; and though I do not presume to advance farther, I perhaps may assist in clearing the way for future naturalists, and, by establishing effects, encourage them to proceed to causes, and help them to discover the powers and agents by which these grand operations have been executed.

Enquiry into the Formation of our perpendicular Façades.

It is natural that the first great operation we proceed to investigate, should be the formation of our magnificent façades, one of which is the principal subject of this memoir.

The line of coast that bounds our basaltic area on its north side, extends about twenty-five Irish miles, in which course the precipices are nearly continuous, and more than one half of them absolutely perpendicular for a great part of their stupendous height. The operation by which they were cut off so abruptly, and left with a formidable aspect towering over our coast, is the one we inquire into.

That these bold precipices once projected farther in many places is easily demonstrated; at Beanyn Daana, and at the Chimney, the columnar construction was obviously once carried much farther out.

At the Milestone, Portcooan, and Portnabau, the fragments of dykes extend far beyond the face of the precipice.

These same facts, together with the projecting base, show that these sudden abruptions were not formed by the subsiding, and sinking of one part, leaving the remainder in its place: still less by any violent revolution, or convulsion; as the stratification has not sustained the slightest shock either above or below the façade.

The formation of our abrupt coast, has been ascribed to the action of the sea beating violently against it, washing away the lower parts, and leaving a perpendicular façade standing; as we often see on the banks of rapid and encroaching rivers.

A cool examination of our precipices will soon prove that our façades could not have been so formed, for we always find them on the highest part of the cliff, and receding from the water, which could be instrumental in bringing down the materials from above, only by washing, and so wearing away the bases of the steepest parts; but the elevations of these bases are utterly irreconcileable to this supposition; for instance, the base of Pleskin façade is two hundred feet above the present level of the sea, that of Fairhead three hundred: now had the sea ever risen to either height, it would have submerged a great part of Ireland, and none of the neighbouring country (whatever its level may be) bears the least resemblance to alluvial ground, nor shows any mark of having been once covered by the sea.

The next argument is still more conclusive; the boundary of our

basaltic area on its north side, is for twenty-five miles also the confine of sea and land; so far it is natural to ascribe its features and characteristic marks, to the action of the powerful element that beats against it. But when that precipitous boundary ceases to be the confine of sea and land, turns southward towards the interior, and becomes the line of demarcation between the basaltic and schistose country on the west, it still preserves its former character; that is, of a range or ridge of very high land, steep to the exterior, and sometimes cut down vertically into façades, like its northern part that lines the shore.

Thus Magilligan Rock (four miles inland) is not inferior in magnificence to any of our façades on the coast, its perpendicular section is one hundred and seventy feet, and this continuous for a mile; the façades at Bienbraddock, are nine miles farther inland, and those of Monyneeny thirteen; while the base of the lowest of these perpendicular precipices is elevated 1400 feet above the sea.

The same style prevails on the east side of our basaltic area, after its boundary ceases to be the confine of sea and land; for the limestone façades at Garron Point (considerably above the level of the sea) exactly resemble those of Dunluce and Kenbaan at the water edge; and Cave Hill (several miles from the sea, and nearly one from the shallow estuary of Belfast), exhibits basaltic façades at the height of one thousand feet, precisely similar, little inferior to those of Magilligan.

The exact resemblance between our inland façades (on the east and west sides of our area) to those on the shore, proves them to be all effects from the same cause, and that our accumulated strata have in all these similar instances been cut down vertically by the same agent, and that this agent was not the sea.

Nor has this powerful agent confined its operations to our coast, or to the periphery of our basaltic area; we can trace it over its whole surface: we find throughout its interior, similar though very diminutive abruptions, executed precisely in the same manner, that is, strata cut across by a long vertical façade, their planes on the upper side perfectly undisturbed, while on the lower side all the materials of which that part of the stratum was once composed are completely carried off.—(See 6th fact.)

We are now unavoidably led into a discussion of a question which has at all times occupied the attention of naturalists.

Whence arise the Inequalities with which the Surface of the Earth is so exceedingly diversified?

I shall not attempt to encounter this question generally, nor to extend my enquiries beyond the limits I have prescribed to myself; but I shall try whether the curious facts so profusely exhibited over our basaltic area, throw any light upon the formation of our own inequalities, or lead us a step towards the discovery of the operations by which such stupendous effects have been produced.

Some, to escape the difficulties in which this question is involved, ascribe our inequalities to original formation; as if the world had come from the hand of the Creator with the variegated surface which now contributes so much to its beauty; but the frequent interruptions, and resumptions of the strata in our area, with the perfect resemblance of the corresponding parts, however great the interval by which they are separated, can scarcely leave a doubt that these strata were at first continuous; of course the figure of our surface at that time must have depended on the original positions and inclinations of these strata, which, as appears by the 3d fact, are now unconnected with the superficial line, the figure of which is governed by their abruptions and removals alone.

Naturalists have differed much in opinion as to the direction in which the causes acted that produced the inequalities on the surface of our globe; some referring us to the bowels of the earth as to the scene of action; while others assert that the operations were performed upon the surface itself.

But the slightest inspection of our façades will at once prove that the first hypothesis cannot be correct; for obliquity of direction must have been the result of a disturbing cause acting from below: whereas parallelism and a steady rectilinear course distinguish the basaltic arrangements of which I have been treating.

We have, it is true, occasional depressions of our strata, where they obviously have subsided, and no doubt from a failure of support below; but in no instance that I have met with, in our area, are these attended by the slightest concussion; the permanent and subsided parts, with us still preserve their parallelism, and the continuity of their material; whence it is probable this event took place previous to the induration of the strata, and of course antecedent to the period to which I limit myself.

Buffon ascribes our superficial inequalities to the agitation of the

waters while they covered our earth, and argues from the resemblance these inequalities bear to the waves of the sea; a resemblance I cannot trace in any country which I have observed; nor could our sudden and perpendicular abruptions, ever have been produced by any agitation of the waters.

Professor Playfair considers rivers as having formed not only the beds, or channels in which they flow, but also the whole of the vallies through which they run, and in general all the inequalities of our surface; but an attentive observer, tracing the course of any of our rapid rivers, would soon perceive that the quantity of its depredations has been comparatively insignificant, and that they can be determined with precision; the river has no doubt in several places extended itself considerably on both sides, but in the intermediate space between the remotest boundaries it ever reached, it levels, instead of raising inequalities.

The same result I apprehend would follow from the operations of another agent, which theorists are in the habit of calling in to their aid, when they cannot find some certain material, which from their theory we had reason to expect; they then tell us it has been carried off, and lost in the suite of degradations and decompositions.

But decay and decomposition, instead of creating inequalities, would produce a contrary effect, and deface those actually existing; they would gradually abate the height of our perpendicular façades, and increase the green steep at their bases by the accumulation of the crumbling and mouldering material from above; while the more diminutive façades formed by the abruptions of single strata scattered over the face of our area, and forming its most characteristic feature, would in time (as many are already) be converted into steep acclivities covered with verdure.

Such are the principal causes to which the inequalities of our surface have been generally ascribed. Previous to our deciding finally upon their insufficiency, it may be proper to enumerate a few of those inequalities, where the deviation of our present surface, from the form it probably had originally, is not only striking, but where also the concomitant circumstances afford demonstration, that some great operation has once taken place there.

Thus, by making ourselves acquainted with effects, we shall be better qualified to investigate causes; and if those effects shall appear to be beyond the powers of such natural agents as we are

already acquainted with, we shall be justified in admitting the performance of operations to which we have seen nothing similar; and also in admitting the former existence of powers of far superior energy to any we have ever known in action.

Enumeration of some remarkable Inequalities in the Surface of our basaltic Area, produced since the Consolidation of its Strata.

That we may better understand the facts I am proceeding to state, I shall assume (in the style of the mathematicians *puta factum*) previous to demonstration, that the planes of our uniform, rectilineal strata, however interrupted we may now find them, were once continuous.

Upon this supposition, the valley of the Mayola, between the stratified summits of Seafin and Slievegallon, is an excavation 1700 feet deep, and three miles wide, of which the whole materials have been completely carried off.

To the northward of this excavation, between Seafin and Carntogher, the continuous accumulated strata of basalt are interrupted, and taken away quite down to the schistose substratum; while the untouched summits of the contiguous mountains, Carntogher, Seafin, and Monaneeny, are still stratified basalt.

On the eastern side of our area, immediately to the southward of Kello and Connor, a similar operation has been performed, attended by still more extraordinary circumstances.

We here find a district near four miles in diameter, called the Sandy Braes; over this whole space the basaltic stratification has been carried off, and the operation has reached deep into a very singular substratum; a reddish breccia, by some mineralogists called a porphyry, the mass friable, but the component angular particles of extreme hardness.

The hills, of which this little district is full, are every one perfect segments of spheres, while the loftier basaltic hills that surround it preserve their characteristic form, to wit, a gradual acclivity on one side, with a steep abruption on the other.

As we sail along our northern shore we discover another great chasm or interruption of our strata, which also cuts deep into the substrata; for on the west side of Ballycastle pier the bold basaltic

precipices suddenly disappear, and at a lower level disclose the substratum, which appears to be an alternation of sand-stone and coal, sometimes with bituminous schistus.

A mile or two to the eastward the abrupt precipice is resumed, and a basaltic stratum again occupies its summit on to Fairhead, with the same angle of inclination in which it was disposed along our whole coast, that is, a slight ascent to the north.

Traces of similar operations and abruptions are to be found over our whole area, but the preceding are sufficient to make us acquainted with the style of these interruptions of our strata; of course it is time to proceed to the suspended demonstration, that our strata, so interrupted, were once continuous, notwithstanding the magnitude of the interval by which the corresponding parts are now separated.

Proofs that our now interrupted Strata were once continuous.

We must now turn back to the façades of Bengore, where the strata themselves, and all the circumstances attending them, are so happily displayed, as to throw great light on the subject, and to lead us analogically, step by step, to the conclusion we seek for.

Let us examine and trace the summit of the precipice for a mile immediately eastward from the Giant's Causeway, and we shall find a frequent interruption and resumption of the fourth, fifth, and sixth strata, at the shortest intervals, the interruption not always reaching to the lowest of the three, which in that case remains continuous: so far simple inspection removes all doubt, that each of these strata was once continuous as far as the great depression to the west of Pleskin.

Here indeed the interruption becomes considerable, not less than a mile; but when we find at Portmoon a succession of three strata with the same inclination, in the same order, of the same thickness each, and with the same strong characteristic marks that distinguished the three interrupted, at the depression; above all, when we find the strata they rest upon continuous (at least with very trifling interruptions) for the same extent, I think we can scarcely entertain a doubt that this interval between the corresponding parts, though so much greater than any of the preceding, is, like them, but an interruption, and that these strata were once continuous from the depression to Portmoon.

The same style of induction would establish the quondam continuity of all the strata in the face of Bengore promontory, for here the strata are so distinctly marked that we know each of them when we find it again after any interruption.

In the rest of the precipices and façades, the similarity of the strata deprives us of this advantage; yet in their smaller interruptions, by tracing the rectilinear course of the strata, and so connecting the separated parts, we can establish their former continuity: while in the greater intervals we must rest our proof on analogy alone.

That we may be entitled to carry this style of induction into the interior of our basaltic area, and to apply the same reasoning to enable us to form a similar decision upon the more stupendous interruptions of our strata, which I have already enumerated, it becomes necessary to explain the geological construction of our area,—the strata of which it is formed—their arrangement—and their inclinations.

An extensive limestone stratum, white as chalk, and about two hundred feet thick, seems to form the base of the whole district I limit myself to: upon this, accumulations of rectilineal and parallel basaltic strata, are heaped up to most unequal heights.

This great calcareous stratum seems not to be an accurate plane, but rather to resemble a bason, as every where at its periphery it dips to the interior; yet the plane of its section has a light ascent to the southward: a recollection of these circumstances will enable us to account for every appearance this stratum exhibits, as it happens to be disclosed to us; and by the converse, an attention to these appearances will enable us accurately to determine the position of the stratum.

This stratum, from Ballycastle to Solomon's Porch (about twenty-five miles) keeps very nearly the level of the sea, often indeed sinking below the surface, but never raising its lower edge above it; but when at Solomon's Porch, the boundary of our basaltic area begins to deflect to the south-west, and then to the south, the ascent of the stratum to the southward begins to operate, and we perceive the dotted line of its quarries gradually to rise along the face of the mountain from the shore to Monyneeny and Seafin, where it has attained the height of 1500 feet: it is true, the actual stratum has not been opened at these two great elevations, but the white rubble in-

mediately below the basaltic façade proves incontestably that it is close at hand.

An accumulation of basaltic strata, had in this southern course, as well as on the northern shore, covered the limestone up to the summits of the hills or mountains.

I have already stated how the ridge of mountain is suddenly interrupted by the valley of the Mayola, from 1600 to 1700 feet deep, but if we look to the southward, in the rectilineal course of the strata the positions of which we have been able to ascertain with so much accuracy), we shall find near the summit of the mountain Slievegallon a similar white limestone stratum crowned with basalt, cutting it in the very direction the former ought to have reached it, that is perhaps two hundred feet higher, the ascent of the strata to the southward having elevated their planes so much in a distance of four miles, the probable interval between the summits of these mountains.

We are now to decide whether this calcareous and basaltic fragment, on the summit of Slievegallon mountain, be the last remnant of the old arrangement we have been tracing, and ascertaining with so much precision, for seventeen or eighteen miles from the sea, and twenty-five miles along the coast, but now interrupted by the valley of the Mayola, like our former more diminutive interruptions, and also like them resumed at the next elevation, in the same rectilineal course, the strata preserving the same order, and the same characteristic marks. Or whether the strata, appearing on the summit of Slievegallon, be the commencement of a new arrangement, abandoned by nature as soon as begun: which is highly improbable, for neither limestone nor basalt are to be found on the mountain except in this solitary hummock.

We might, by a minute attention to the inclinations and arrangements of the strata contiguous to the other interruptions I have enumerated, prove in like manner that the basaltic masses crowning the summits of the surrounding hills and mountains, are merely the remnants of strata once extensive and continuous, but interrupted and carried off, as in the preceding case, by the same powerful agent.

The more diminutive inequalities scattered over the whole surface of our area, and always produced by interruptions of the strata,

would still more easily admit the application of the same reasoning, from the contiguity of their abrupted parts; but the detail would be tedious; those who wish to pursue the subject farther must come to the scene themselves.

Materials completely carried off.

A circumstance perhaps still more extraordinary, is the complete removal of all the materials that once filled up the intervals between the abrupted parts of these strata; I have stated in my 9th fact, that the materials that had formerly composed the projecting parts of our northern façades and precipices had totally disappeared.

The removed parts of the limestone stratum on the west side of our area have shared the same fate, for where the chain of mountains extending from Magilligan Rock to Bienbraddock, is interrupted by vallies at Stradreagh, Drumrommer, and Ballyness, it is obvious that the limestone stratum was once continuous to the high points where it shows itself on Keady, and the mountains on each side; its thickness too, wherever we can try it, is very great; yet this stratum, which in its entire state must have spread like a roof far above the present surface of these valleys (which are now sunk deep into the schistose substratum) has not left a particle of its *debris* behind, nor is a single lump of white limestone to be found until we come to the quarries, that is, to the edge of the solid, untouched stratum.

Conclusions.

The conclusions that unavoidably follow, from the consideration of these facts, are,

That the hills and mountains, in the district that I have been describing, were not raised up or formed as they now stand, but that they are the undisturbed remains of strata that were left behind, when stupendous operations carried away the parts that were once contiguous to them.

That the inequalities of this surface were all produced by causes acting from above, and carrying off whatever they touched, without in the least disturbing what was left behind.

*Additional Evidences. Basaltic Hummocks.**

The arguments on which I have founded my opinions have hitherto been all taken from the hollows in our surface, and the interruptions in our strata, both which the concomitant circumstances have led me to consider as so many excavations; but the lofty elevations, and the abrupt prominencies rising suddenly from our surface, when minutely examined, lead us irresistibly to the very same conclusion.

When you and I examined together the line of our northern façades, we studiously sought for the points where nature had made any change in her materials or their arrangement, hoping that at the junctions of these little systems, we should find some facts that would throw light on the subject; but we generally failed; want of perpendicularity, or other local circumstances, impeding us at the most interesting points.

On the present occasion she has adopted an opposite line of conduct, and in many of the steps she has taken, obtrudes upon us demonstration of what she has done.

Whoever has attended to the exertions of man, when employed in altering our present surface, either by levelling heights, or by making excavations, must have observed that it is the practice of the workmen to leave small, cylindrical portions standing, for the purpose of determining the height of the old surface, and thereby ascertaining the quantity of materials removed.

To these may be compared the stratified basaltic hummocks so profusely scattered over our area, and which seem to shew how high our quondam surface once reached.

The hummock of Dunmull, three miles south-east from Portrush, is very beautiful, it stands on the top of a high ridge, and is a conspicuous object from all parts of the country; it is exactly circular, its flat surface contains an acre, it is completely surrounded by a perpendicular façade about twenty-five feet high, and formed by two strata, a columnar, and an irregular prismatic, resting upon it.

From this elevated station, where I had the pleasure of accom-

* Navigators use the word *hummock* to express circular and elevated mounts, appearing at a distance; I adopt the term from them.

panying you, I shewed you at six or seven miles distance to the westward, among the Derry mountains, the still loftier hummocks of Altabrian and Sconce, hemispherical in form, composed of but one stratum each, while their swelling-out bases displayed accumulations of many more: and also near those the hummock of Fermayle, resembling Dunmull, but much larger, and also surrounded by a façade composed of two strata.

I shewed you also at twenty miles distance to the south east, the gigantic Slemish, one of our basaltic hummocks, magnified (as it were) into a lofty and insulated mountain, completely stratified from its base to its flat summit.

I shewed you likewise from the bottom of its ridge, the neat but diminutive hummock, called the Rock of Clogher, above Bushmills. As our time was precious, you took my word for its stratification being precisely similar to that of Dunmull.

There are many other basaltic hummocks scattered over the surface of our area, all of them either stratified or portions of strata; two of the most remarkable are the hill of Knock Loughran, near Maghera, and a tall hummock (whose name I forget) a mile eastward from Lismore.

We meet still more frequently an imperfect style of hummock, a semi-circular façade on one side, while on the other it slopes away gradually with the dip of the strata, as if the operation had been interrupted before it was carried quite round; the most remarkable of these are Ballystrone, in Derry, and Croaghmore, in Antrim, both visible from Dunmull.

Regular stratifications on the summits of hills and mountains, have been long a stumbling block to theorists; the historian of the French Academy, for the year 1716, obviously ascribing the superficial inequalities of the earth, (like many others) to causes acting from below, and perceiving how incompatible such assemblages of strata were to his theory, thinks it safer to doubt their existence, as they could not have been formed, he says " unless the masses of the mountains were elevated in the direction of an axis perpendicular to the horizon: *ce que n'a pu être que très rare.*"

But as these stratified mounts are in our area by no means uncommon, they lay us under the necessity of suggesting another alternative similar to those we have already stated.

Were these isolated hummocks originally formed as they now

stand, (solitary and separate from each other) one by one; or, are they the last remaining portions of a vast consolidated mass, of which the intermediate and connecting strata have been carried off by causes with which we are unacquainted?

To be able satisfactorily to resolve this alternative, it becomes necessary to take a careful view of the contiguous countries, and to try whether their construction, and the arrangement of their strata, will throw any light upon the subject.

When we examine the assemblage of hummocks above Knock-mult, that is, Sconce, Fermoyle, and Altabrian, we find their materials and stratification precisely similar to that of the country below them to the eastward, where the abruptions of the strata are displayed in long stony ridges;—to the south, the abruptions on the summit of Keady mountain discover the same similarity; and to the north-west the grand façade of Magilligan Rock, three miles distant, displays an accumulation of exactly the same sort of strata consolidated into an enormous mass.

The hummock of Dunmull is formed of two very particular strata, a columnar, and an irregular prismatic; but I shewed you, a mile to the northward, at the façades and quarries of Islamore and Draigahuller, at the base of the hill, that the whole ridge, on the summit of which Dunmull is placed, was a consolidated mass, formed by alternate strata of the same description; and that the arrangement of the whole country below, and adjacent, was precisely the same with that of the hummock of Clogher, I proved to you at the curious opening of the strata at Bushmills Bridge, and in the façades at the Giant's Causeway.

After these proofs that so many (and I might proceed to the rest) of our detached hummocks are in their construction and materials, similar to, and connected with, the main consolidated masses of which our country is formed, I think it will scarcely be asserted that these hummocks were originally formed, solitary and separate as they now stand: but rather that they were once parts of that vast whole, and left behind in their present form, upon the removal of the contiguous portions of their strata, by some powerful agent, of whose operations and modes of acting, we have hitherto obtained little knowledge

The highest point on the façade of Cave Hill is called M'Art's Castle, and appears to be a solitary fragment of a stratum pre-

cisely similar to those below it, and obviously once extended like them.

The irregularity of the summit of Fairhead, plainly shews that its gigantic columns once reached higher.

And in the façade of Magilligan, the highest of all, a few desultory patches of an upper stratum (no doubt once perfect and continuous) are to be traced along its summit.

Our mountains themselves seem to shew clearly that they were once higher; the top of Magilligan mountain is an extensive plain, over which a wandering stratum is interrupted and resumed at intervals for a great way.

At the highest part of Donald's Hill, over the valley of Glenuller, we find a hummock; also at the termination of the ridge, at its highest part over the valley of Mayola, similar hummocks.

[*Phil. Trans.* Vol. XCVIII. 1808.]

CHAP. V.

GEOGRAPHY, OR THE DOCTRINE OF THE GENERAL FACE OF THE EARTH.

In the sense in which we have already stated it is our intention to use the term GEOLOGY, *Geography* holds the same relation to it as *Geognosy*; the former constituting that department of Geology which contemplates the actual surface of the Earth, as the latter constitutes that department which describes its apparent origin and chemical structure. We shall briefly contemplate the science under the two sections of its history and its principles.

SECT. I.—*History of Geography.*

The study of geography being of so much practical importance in life, must have commenced in the early ages of the word. It was regarded as a science by the Babylonians and Egyptians, from whom it passed to the Greeks, and from these to the Romans, the Arabians, and the western nations of Europe. Thales of Miletus, in the 6th

century before Christ, first made observations on the apparent progress of the sun from tropic to tropic; and is said to have written two treatises, the one on the tropic, and the other on the equinox, whence he was led to the discovery of the four seasons, which are determined by the equinoxes and solstices. We are assured this knowledge was obtained by means of the gnomon. Thales, it is also said, constructed a globe, and represented the land and sea upon a table of brass.

Meton and Euctemon observed the summer solstice at Athens, on the 27th of June, 432 years before Christ, by watching narrowly the shadow of the gnomon, with the design of fixing the beginning of their cycle of 19 years.

Timocharis and Aristillus, who began their observations about 295 B.C., first attempted to fix the latitudes and longitudes of the fixed stars, by considering their distances from the equator, &c. One of their observations gave rise to the discovery of the precession of the equinoxes, which was first remarked by Hipparchus about 150 years after; who also made use of their method for delineating the parallels of latitude and the meridians, on the surface of the earth; thus laying the foundation of this science as it now appears.

The latitudes and longitudes, thus introduced by Hipparchus, were not however much attended to till Ptolemy's time. Strabo, Vitruvius, and Pliny, have all of them entered into a minute geographical description of the situation of places, according to the length of the shadows of the gnomon, without noticing the longitudes and latitudes.

Maps at first were little more than rude outlines, and topographical sketches of different countries. The earliest on record were those of Sesostris, mentioned by Eustathius, who says, that "this Egyptian king, having traversed great part of the earth, recorded his march in maps, and gave copies of them not only to the Egyptians, but to the Scythians, to their great astonishment." Some have imagined, with much probability, that the Jews made a map of the Holy Land when they gave the different portions to the nine tribes at Shiloh; for Joshua tells us that they were sent to walk through the land, and that they described it in seven parts in a book; and Josephus relates that when Joshua sent out people from the different tribes to measure the land, he gave them as companions

persons well skilled in geometry, who could not be mistaken in the truth.

The first Grecian map on record was that of Anaximander, mentioned by Strabo, supposed to be that referred to by Hipparchus under the designation of the ancient map. Herodotus minutely describes a map made by Aristagoras, tyrant of Miletus, which will serve to give some idea of the maps of those times. He relates, that Aristagoras shewed it to Cleomenes, king of Sparta, to induce him to attack the king of Persia at Susa, in order to restore the Ionians to their ancient liberty. It was traced upon brass or copper, and seems to have been a mere itinerary, containing the route through the intermediate countries which were to be traversed in that march, with the rivers Halys, the Euphrates, and Tigris, which Herodotus mentions as necessary to be crossed in that expedition. It contained one straight line called the royal road, or highway, which took in all the stations or places of encampment from Sardis to Susa; being 111 in the whole journey, and containing 13,600 stadia, or 1687½ Roman miles of 5000 feet each.

Eratosthenes first attempted to reduce geography to a regular system, and introduced a regular parallel of latitude, which began at the Streights of Gibraltar, passed eastwards through the isle of Rhodes, and so on to the mountains of India, noting all the intermediate places through which it passed. In drawing this line, he was not regulated by the same latitude, but by observing where the longest day was 14 hours and a half, which Hipparchus afterwards determined was the latitude of 36 degrees.

This first parallel through Rhodes was ever after considered with a degree of preference, in constructing all the ancient maps; and the longitude of the then known world was often attempted to be measured in stadia and miles, according to the extent of that line, by many succeeding geographers.

Eratosthenes soon after attempted not only to draw other parallels of latitude, but also to trace a meridian at right angles to these, passing through Rhodes and Alexandria down to Syene and Meroe; and at length he undertook the arduous task of determining the circumference of the globe, by an actual measurement of a segment of one of its great circles. To find the magnitude of the earth is indeed a problem which has engaged the attention of astronomers and geographers ever since the spherical figure of it was known.

It seems Anaximander was the first among the Greeks who wrote upon this subject. Archytas of Tarentum, a Pythagorean, famous for his skill in mathematics and mechanics, also made some attempts in this way; and Dr. Long conjectures that these are the authors of the most ancient opinion that the circumference of the earth is 400,000 stadia; and Archimedes makes mention of the ancients who estimated the circumference of the earth at only 30,000 stadia.

As to the methods of measuring the circumference of the earth, it would seem, from what Aristotle says in his treatise de Cœlo, that they were much the same as those used by the moderns, deficient only in the accuracy of the instruments. That philosopher there says, that different stars pass through our zenith, according as our situation is more or less northerly; and that in the southern parts of the earth stars come above our horizon, which are no longer visible if we go northward. Hence it appears that there are two ways of measuring the circumference of the earth; one by observing stars which pass through the zenith of one place, and do not pass through that of another; the other, by observing some stars which come above the horizon of one place, and are observed at the same time to be in the horizon of another. The former of these methods, which is the best, was followed by Eratosthenes at Alexandria in Egypt, 250 years before Christ. He knew that at the summer solstice, the sun was vertical to the inhabitants of Syene, a town on the confines of Ethiopia, under the tropic of Cancer, where they had a well made to observe it, at the bottom of which the rays of the sun fell perpendicularly the day of the summer solstice: he observed by the shadow of a wire set perpendicularly in an hemispherical bason, how far the sun was on that day at noon distant from the zenith of Alexandria; when he found that distance was equal to the 50th part of a great circle in the heavens. Then supposing Syene and Alexandria under the same meridian, he inferred that the distance between them was the 50th part of a great circle upon the earth; and this distance being by measure 5000 stadia, he concluded that the whole circumference of the earth was 250,000 stadia. But as this number divided by 360 would give $694\frac{4}{9}$ stadia to a degree, either Eratosthenes himself, or some of his followers, assigned the round number 700 stadia to a degree, which multiplied by 360, makes the circumference of the earth 252,000 stadia; whence

both these measures are given by different authors as that of Eratosthenes.

In the time of Pompey the Great, Posidonius determined the measure of the circumference of the earth by the 2d method above hinted by Aristotle, viz. the horizontal observations. Knowing that the star called Canopus was but just visible in the horizon of Rhodes, and at Alexandria finding its meridian height was the 48th part of a great circle in the heavens, or $7\frac{1}{2}$ degrees, answering to the like quantity of a circle on the earth; then supposing these two places under the same meridian, and the distance between them 5000 stadia, the circumference of the earth will be 240,000 stadia; which is the first measure of Posidonius. But according to Strabo, Posidonius made the measure of the earth to be 180,000 stadia, at the rate of 500 stadia to a degree. The reason of this difference is thought to be, that Eratosthenes measured the distance between Rhodes and Alexandria, and found it only 3750 stadia; taking this for a 48th part of the earth's circumference, which is the measure of Posidonius, the whole circumference will be 180,000 stadia. This measure was received by Marinus of Tyre, and is usually ascribed to Ptolemy. But this measurement is subject to great uncertainty, both on account of the great refraction of the stars near the horizon, the difficulty of measuring the distance at sea between Rhodes and Alexandria, and by supposing those places under the same meridian, when they are really very different.

Several geographers afterwards made use of the different heights of the pole in distant places under the same meridian, to find the dimensions of the earth. About the year 800 the khalif Almemun had the distance measured between two places that were two degrees asunder, and under the same meridian, in the plains of Sinjar on the Red Sea; and the result was, that the degree at one time was found equal to 56 miles, and at another $56\frac{1}{3}$ or $56\frac{2}{3}$ miles.

The next attempt to find out the circumference of the earth was in 1525, by Fernelius, a learned philosopher of France. For this purpose he took the height of the pole at Paris, going thence directly northwards, till he came to the place where the height of the pole was one degree more than at that city. The length of the way was measured by the number of revolutions made by one of the wheels of his carriage; and after proper allowances for the declivities and

turnings of the road, he concluded that 68 Italian miles were equal to a degree of the earth.

According to these methods many other measurements of the earth's circumference have since that time been made, with much greater accuracy.

Though the maps of Eratosthenes were the best of his time, they were yet very imperfect and inaccurate. They contained little more than the states of Greece, and the dominions of the successors of Alexander, digested according to the surveys above-mentioned. He had indeed seen, and has quoted, the voyages of Pythias into the great Atlantic ocean, which gave him some faint ideas of the western parts of Europe; but so imperfect, that they could not be realized into the outlines of a chart. Strabo says he was very ignorant of Gaul, Spain, Germany, and Britain; and he was equally ignorant of Italy, the coast of the Adriatic, Pontus, and all the countries towards the north.

Such was the state of geography, and the nature of the maps, before the time of Hipparchus. He made a closer connection between geography and astronomy, by determining the latitudes and longitudes from celestial observations.

War has usually been the occasion of making or improving the maps of countries; and accordingly geography made great advances from the progress of the Roman arms. In all the provinces occupied by that people, camps were every where constructed at proper intervals, and good roads made for communication between them; and thus civilization and surveying were carried on according to system through the whole extent of that large empire. Every new war produced a new survey and itinerary of the countries where the scenes of action passed; so that the materials of geography were accumulated by every additional conquest. Polybius says, that at the beginning of the second Punic war, when Hannibal was preparing his expedition against Rome, the countries through which he was to pass were carefully measured by the Romans. And Julius Cæsar caused a general survey of the Roman empire to be made, by a decree of the senate. Three surveyors had this task assigned them, which they completed in twenty-five years. The Roman itineraries that are still extant, also shew what care and pains they had been at in making surveys in all the different provinces of their empire, and Pliny has filled the 3d, 4th, and 5th books of his Natural History

with the geographical distances that were thus measured. Other maps are also still preserved, known by the name of the Peutigerian Tables, published by Welser and Bertius, which give a good specimen of what Vegetius calls the *itinera picta*, for the better direction of their armies in their march.

The Roman empire had been enlarged to its greatest extent, and all its provinces well known and surveyed, when Ptolemy, about 150 years after Christ, composed his system of geography. The chief materials he employed in composing this work, were the proportions of the gnomon to its shadow, taken by different astronomers at the times of the equinoxes and solstices; calculations founded on the length of the longest days; the measured or computed distances of the principal roads contained in their surveys and itineraries; and the various reports of travellers and navigators. All these were compared together, and digested into one uniform body or system; and afterwards were translated by him into a new mathematical language, expressing the different degrees of latitude and longitude, after the invention of Hipparchus, which had been neglected for 250 years.

Ptolemy's system of geography, notwithstanding it was still very imperfect, continued in vogue till the last three or four centuries, within which time the great improvements in astronomy, the many discoveries of new countries by voyagers, and the progress of war and arms, have contributed to bring it to a very considerable degree of perfection.

SECT. II.—*Principles of Geography.*

The fundamental principles of geography are, the spherical figure of the earth, its rotation on its axis, its revolution round the sun, and the position of the axis or line round which it revolves with regard to the celestial luminaries. That the earth and sea taken together constitute one vast sphere, is demonstrable by the following arguments: 1. To people at sea the land disappears, though near enough to be visible were it not for the intervening convexity of the water. 2. The higher the eye is placed, the more extensive is the prospect; whence it is common for sailors to climb up to the tops of the masts to discover land or ships at a distance. But this would give them no advantage, were it not for the convexity of the earth; for upon an

infinitely extended plane objects would be visible at the same distance whether the eye was high or low, nor would any of them vanish till the angle under which they appeared became too small to be perceived. 3. To people on shore the mast of a ship at sea appears before the hull; but were the earth an infinite plane, not the highest objects, but the largest, would be longest visible; and the mast of a ship would disappear, by the smallness of its angle, long before the hull did so. 4. The convexity of any piece of still water of a mile or two in extent may be perceived by the eye. A little boat, for instance, may be perceived by a man who is any height above the water; but if he stoops down or lays his eye near the surface, he will find that the fluid appears to rise and intercept the view of the boat entirely. 5. The earth has been often sailed round, as by Magellan, Drake, Dampier, Anson, Cook, and many other navigators, which demonstrates that the surface of the ocean is spherical; and that the land is very little different, may easily be proved from the small elevation of any part of it above the surface of the water. The mouths of rivers which run 1000 miles are not more than one mile below their sources, and the highest mountains are not quite four miles of perpendicular height; so that, though some parts of the land are elevated into hills, and others depressed into valleys, the whole may still be accounted spherical. 6. An undeniable, and indeed ocular, demonstration of the spherical figure of the earth is taken from the round figure of its shadow which falls upon the moon in time of eclipses. As various sides of the earth are turned towards the sun during the time of different phænomena of this kind, and the shadow in all cases appears circular, it is impossible to suppose the figure of the earth to be any other than spherical. The inequalities of its surface have no effect upon the earth's shadow on the moon; for as the diameter of the terraqueous globe is very little less than 8000 miles, and the height of the highest mountains on earth not quite four, we cannot account the latter any more than the 2000th part of the former, so that the mountains bear no more proportion to the bulk of the earth, than grains of dust bear to that of a common globe.

A great many of the terrestrial phænomena depend upon the globular figure of the earth, and the position of its axis with regard to the sun, particularly the rising and setting of the celestial luminaries, the length of the days and nights, &c.

Though the sun rises and sets all over the world, the circumstances of his doing so are very different in different countries. The most remarkable of these circumstances is the duration of the light, not only of the sun himself, but of the twilight before he rises, and after he sets. In the equatorial regions, for instance, darkness comes on very soon after sunset; because the convexity of the earth comes quickly in between the eye of the observer and the luminary, the motion of the earth being much more rapid there than any where else. In our climate the twilight always continues two hours, or thereabouts, and during the summer season it continues in a considerable degree during the whole night. In countries farther to the northward or southward, the twilight becomes brighter and brighter as we approach the poles, until at last the sun does not appear to touch the horizon, but goes in a circle at some distance above it for many days successively. In like manner, during the winter, the same luminary sinks lower and lower, untill at last he does not appear at all; and there is only a dim twinkling of twilight for an hour or two in the middle of the day. By reason of the refraction of the atmosphere, however, the time of darkness, even in the most inhospitable climates, is always less than that of light; and so remarkable is the effect of this property, that in the year 1682, when some Dutch navigators wintered in Nova Zembla, the sun was visible to them sixteen days before he could have been seen above the horizon, had there been no atmosphere. The reason of all this is, that in the northern and southern regions only a small part of the convexity of the globe is interposed betwixt us and the sun for many days, and in the high latitudes none at all. In the warmer climates the sun has often a beautiful appearance at rising and setting, from the refraction of his light through the vapours which are copiously raised in those parts. In the colder regions, halos, parhelia, aurora borealis, and other meteors are frequent; the two former owing to the great quantity of vapour continually flying from the warm regions of the equator to the colder ones of the poles. In the high northern latitudes, thunder and lightning are unknown, or but seldom heard of; but the more terrible phænomena of earthquakes, volcanoes, &c. are by no means unfrequent. These, however, seem only to affect islands and the maritime parts of the continent.

Notwithstanding the seeming inequality in the distribution of light and darkness, however, it is certain, that throughout the whole

world there is nearly an equal proportion of light diffused on every part, abstracting from what is absorbed by clouds, vapours, and the atmosphere itself. The equatorial regions have indeed the most intense light during the day, but the nights are long and dark; while, on the other hand, in the northerly and southerly parts, though the the sun shines less powerfully, yet the length of time that he appears above the horizon, with the greater duration of the twilight, compensates for the seeming deficiency.

Were the earth a perfect plane, the sun would appear to be vertical in every part of it; for, in comparison with the immense magnitude of that luminary, the diameter of this globe itself is but very small; and as the sun, were he near to us, would do much more than cover the whole earth, so, though he were removed to any distance, the whole diameter of the latter would make no difference in the apparent angle of altitude. By means of the globular figure of the earth also, along with the great disparity between the diameters of the two bodies, some advantage is given to the day over the night; for thus the sun, being immensely the larger of the two, shines upon more than one half of the earth; whence the unenlightened part has a shorter way to go before it again receives the benefit of his rays. This difference is greater in the inferior planets Venus and Mercury than in the earth.

To the globular form of the earth likewise is owing the long moonlight which the inhabitants of the polar regions enjoy. The same figure likewise occasions the appearance and disappearance of certain stars at some seasons of the year in some countries; for, were the earth flat, they would all be visible in every part of the world at the same time. Hence most probably has arisen the opinion of the influence of certain stars upon the weather and other sublunary matters. In short, on the globular figure of the earth depends the whole present appearance of nature around us; and were the shape of the planet we inhabit to be altered to any other, besides the real differences which would of consequence take place, the apparent ones would be so great, that we cannot form any idea of the face which nature would then present to us.

In geography the circles which the sun apparently describes in the heavens are supposed to be extended as far as the earth, and marked on its surface; and in like manner we may imagine as many circles as we please to be described on the earth, and their planes

to be extended to the celestial sphere, till they mark concentric ones on the heavens. The most remarkable of those supposed by geographers to be described in this manner are the following.

1. *The horizon.* This is properly a double circle, one of the horizons being called the sensible, and the other the rational. The former comprehends only that space which we can see around us upon any part of the earth, and which is very different according to the difference of our situation. The other, called the rational, is a circle parallel to the former, and passing through the centre of the earth, supposed to be continued as far as the celestial sphere itself. To the eyes of spectators there is always a vast difference between the sensible and rational horizons; but from the immense disparity betwixt the size of the earth and celestial sphere, planes of both circles may be considered as coincident. Hence in geography, when the horizon, or plane of the horizon, is spoken of, the rational is always understood when nothing is said to the contrary. In consequence of the round figure of the earth, every part has a different horizon. The poles of the horizon, that is, the points directly above the head, and opposite to the feet of the observer, are called the zenith and nadir.

2. A great circle described upon the sphere of the heaven, and passing through the two vertical points, is called a vertical circle, or an azimuth; and of these we may suppose as many as we please all round the horizon. In geography every circle obtains the epithet of great whose plane passes through the centre of the earth; in other cases they are called lesser circles. The altitudes of the heavenly bodies are measured by an arch of the azimuth or vertical circle intercepted between the horizon and body itself. The most accurate method of taking them, with regard to the sun and moon, is for two persons to make their observations at the same time; one of them to observe the altitude of the upper limb, the other of the lower limb of the luminary; the mean betwixt these two giving the true height of the centre. The same thing may also be done accurately by one observer, having the apparent diameter of the luminary given. For, having found the height of the upper edge of the limb by the quadrant, take from it half his diameter, the remainder is the height of his centre; or having found the altitude of his lower edge, add to it half the diameter, and the sum is the height of the centre as before. When the observations are made with a large instru-

ment, it will be convenient to use a sextant, or sixth part of a circle, rather than a quadrant, as being less unwieldy.

3. Almucantars are circles supposed to be drawn upon the sphere parallel to the horizon, and grow less and less as they approach the vertical points, where they entirely vanish. The apparent distances betwixt any two celestial bodies are measured by supposing arches of great circles drawn through them, and then finding how many degrees, minutes, &c. of these circles are intercepted between them.

4. Sometimes the visible horizon is considered only with regard to the objects which are upon the earth itself, in which case we may define it to be a lesser circle on the surface of the earth, comprehending all such objects as are at once visible to us; and the higher the eye, the more is the visible horizon extended. It is most accurately observed, however, on the sea, on account of the absence of those inequalities which at land render the circle irregular; and for this reason it is called sometimes the horizon of the sea, and may be observed by looking through the sights of a quadrant at the most distant part of the sea then visible.

5. The equator is a great circle upon the earth, every part of which is equally distant from the poles or extremities of the imaginary line on which the earth revolves. In the sea language it is usually called the line, and when people sail over it they are said to cross the line.

6. The meridian of any place is a great circle on the earth drawn through that place and both poles of the earth. It cuts the horizon at right angles, marking upon it the true north and south point; dividing also the globe into two hemispheres, called the eastern and western from their relative situation to that place and to one another. The poles divide the meridians into two semicircles, one of which is drawn through the place to which the meridian belongs, the other through that point of the earth which is opposite to the place. By the meridian of a place, geographers and astronomers often mean that semicircle which passes through the place, and which may therefore be called the geographical meridian. All places lying under this semicircle are said to have the same meridian; the semicircle opposite to this is called the opposite meridian. The meridians are thus immovably fixed to the earth as much as the places themselves on its surface, and are carried along with it in its diurnal rotation When the geographical meridian of any place is, by the rotation of

the earth, brought to point at the sun, it is noon or mid-day at that place, in which case, were the plane of the circle extended, it would pass through the middle of the luminary's disk. Supposing the plane of the meridians to be extended to the sphere of the fixed stars, in that case, when by the rotation of the earth the meridian comes to any point in the heavens, then, from the apparent motion of the heavens, that point is said to come to the meridian. The rotation of the earth is west to east; whence the celestial bodies appear to move the contrary way. East and west, however, are terms merely relative, since a place may be west from one part of the earth, and east from another; but the true east and west points from any place are those where its horizon cuts the equator.

7. All places lying under the same meridian are said to have the same longitude, and those which lie under different meridians to have different longitudes; the difference of longitude being reckoned eastward or westward on the equator. Thus, if the meridian of any place cuts the equator in a point 15 degrees distant from one another, we say there is a difference of 15° longitude betwixt these two places. Geographers usually fix upon the meridian of some remarkable place for the first meridian, and reckon the longitude of all others by the distance of their meridians from that which they have determined upon as the first; measuring sometimes eastward on the equator all round the globe, or sometimes only one-half east and the other west; according to which last measurement no place can have more than 180° longitude either east or west. By the ancient Greek geographers the first meridian was placed in Hera or Junonia, one of the Fortunate Islands, as they were then called, which is supposed to be the present island of Teneriffe, one of the Canaries. These islands, being the most westerly part of the earth then known, were on that account made the seat of the first meridian, the longitude of all other places being counted eastward from them. Among modern geographers indeed, it is now become customary for each to make the first meridian pass through the capital of his own country; a practice, however, which is certainly improper, as it is thus impossible for the geographers of one nation to understand the maps of another without a troublesome calculation, which answers no purpose. By the British geographers the royal observatory at Greenwich is accounted the place of the first meridian.

8. If we suppose 12 great circles, one of which is the meridian to

a given place, to intersect each other at the poles of the earth, and divide the equator into 24 equal parts, these are the hour-circles of that place. These are by the poles divided into 24 semicircles, corresponding to the 24 hours of the day and night. The distance betwixt each two of these semicircles is 15°, being the 24th part of 360; and by the rotation of the earth each succeeding semicircle points at the sun one hour after the preceding; so that in 24 hours all the semicircles point successively at the sun. Hence it appears, that such as have their meridian 15° east from any other have likewise noon one hour sooner, and the contrary; and in like manner every other hour of the natural day is an hour sooner at the one place than at the other. Hence, from any instantaneous appearance in the heavens observed at two distant places, the difference of longitude may be found, if the hour of the day is known at each place. Thus the beginning of an eclipse of the moon, when the luminary first touches the shadow of the earth, is an instantaneous appearance, as also the end of an eclipse of this kind, when the moon leaves the shadow of the earth, visible to all the inhabitants on that side of the globe. If therefore we find, that at any place an eclipse of the moon begins an hour sooner than at another, we conclude that there is a difference of 15° of longitude between the two places. Hence also were a man to travel or sail round the earth from west to east, he would reckon one day more to have passed than they do who stay at the place whence he set out; so that their Monday would be his Tuesday, &c. On the other hand, if he sails westward, he will reckon a day less, or be one day in the week later, than those he leaves behind

9. The equator divides the earth into two hemispheres, called the northern and southern; all places lying under the equator are said to have no latitude; and all others to have north or south latitude according to their situation with respect to their equator. The latitude itself is the distance from the equator measured upon the meridian in degrees, minutes, and seconds. The complement of latitude is the difference between the latitude itself and 90°, or as much as the place itself is distant from the pole; and this complement is always equal to the elevation of the equator above the horizon of the place. The elevation of the pole of any place is equal to the latitude itself.

An inhabitant of the earth who lived (if it were possible) at either

of the poles would have always one of the celestial poles in his zenith, and the other in his nadir, the equator coinciding with the horizon. Hence all the celestial parallels are also parallel to the horizon; whence the person is said to live in a parallel sphere, or to have a parallel horizon.

Those who live under the equator have both poles in the horizon, all the celestial parallels cutting the horizon at right angles; whence they are said to live in a right sphere, or to have a right horizon.

Lastly, those who live between either of the poles and the equator, are said to live in an oblique sphere, or to have an oblique horizon, because the celestial equator cuts their horizon obliquely, and all the parallels in the celestial sphere have their planes oblique to that of the horizon. In this sphere some of the parallels intersect the horizon at oblique angles, some are entirely above it, and some entirely below it; all of them, however, so situated, that they would obliquely intersect the plane of the horizon extended.

The largest parallel which appears entire above the horizon of any place in north latitude is called by the ancient astronomers the arctic circle of that place; within this circle, that is, between it and the arctic pole, are comprehended all the stars which never set in that place, but are carried perpetually round the horizon in circles parallel to the equator. The largest parallel which is hid entirely below the horizon of any place in north latitude was called the antarctic circle of that place by the ancients. This circle comprehends all the stars which never rise in that place, but are carried perpetually round below the horizon in circles parallel to the equator. In a parallel sphere, however, the equator may be considered as both arctic and antarctic circle; for, being concident with the horizon, all the parallels on one side are entirely above it, and those on the other entirely below it. In an oblique sphere, the nearer any place is to either of the poles, the larger are the arctic and antarctic circles, as being nearer to the celestial equator, which is a great circle. In a right sphere, the arctic and antarctic circles have no place, because no parallel appears either entirely above or below it. By the arctic and antarctic circles, however, modern geographers in general understand two fixed circles at the distance of 23½ degrees from the pole. These are supposed to be described by the poles of the ecliptic, and mark out the space all round the globe where the sun appears to touch the horizon at midnight in the summer time, and to be en-

tirely sunk below it in the winter. These are also called the polar circles.

According to the different positions of the globe with regard to the sun, the celestial bodies will exhibit different phenomena to the inhabitants. Thus, in a parallel sphere, they will appear to move in circles round the horizon; in a right sphere they would appear to rise, and set as at present, but always in circles, cutting the horizon at right angles; but in an oblique sphere the angle varies according to the degree of obliquity, and the position of the axis of the sphere with regard to the sun. Hence we easily perceive the reason of the sun's continual change of place in the heavens; but though it is certain that this change takes place every moment, the vast distance of the luminary renders it imperceptible for some time, unless to very nice astronomical observers. Hence we may generally suppose the place of the sun to be the same for a day or two together, though in a considerable number of days it becomes exceedingly obvious to every body. When he appears in the celestial equator, his motion appears for some time to be in the plane of that circle, though it is certain that his place there is only for a single moment; and in like manner, when he comes to any other point of the heavens, his apparent diurnal motion is in a parallel drawn throughout. Twice a year he is in the equator, and then the days and nights are nearly equal all over the earth. This happens in the months of March and September, after which the sun proceeding either northward or southward according to the season of the year and the position of the observer, the days become longer or shorter than the nights, and summer or winter is introduced accordingly. The secession of the sun from the equator either northward or southward is called his declination, and is either north or south according to the season of the year; and when this declination is at its greatest height, he is then said to be in the tropic, because he begins to turn back (the word tropic being derived from the Greek τρεπω, *to turn round.*) The space between the two tropics, called the torrid zone, extends for no less than 47 degrees of latitude all round the globe; and throughout the whole of that space the sun is vertical to some of the inhabitants twice a year, but to those who live directly under the tropics only once. Throughout the whole torrid zone also there is little difference between the length of the days and nights. The ancient geographers found themselves considerably

embarrassed in their attempts to fix the northern tropic; for though they took a very proper method, namely, to observe the most northerly place where objects had no shadow on a certain day, yet they found that on the same day no shadow was cast for a space of no less than 300 stadia. The reason of this was, the apparent diameter of the sun, which, being about half a degree, seemed to extend himself over as much of the surface of the earth, and to be vertical every where within that space.

When the sun is in or near the equator, he seems to change his place in the heavens most rapidly; so that about the equinoxes one may very easily perceive the difference in a day or two; but as he approaches the tropics, this apparent change becomes gradually slower, so that for a number of days he scarcely seems to move at all. The reason of this may easily be understood from any map on which the ecliptic is delineated; for by drawing lines through every degree of it parallel to the equator, we shall perceive them gradually approach nearer and nearer each other, until at last, when we approach the point of contact betwixt the ecliptic and tropic, they can for several degrees scarcely be distinguished at all.

From an observation of the diversity in the length of the days and nights, the rising and setting of the sun, with the other phenomena already mentioned, the ancient geographers divided the surface of the earth into certain districts, which they called climates; and instead of the method of describing the situation of places by their latitude and longitude as we do now, they contented themselves with mentioning the climate in which they were situated.

This method of dividing the surface of the earth into climates, though now very much disused, has been adopted by several modern geographers. Some of these begin their climates at the equator, reckoning them by the increase of half an hour in the length of the day northward. Thus they go on till they come to the polar circles, where the longest day is twenty-four hours: betwixt these and the poles they count the climates by the increase of a natural day in the length of time that the sun continues above the horizon, until they come to one where the longest day is fifteen of ours, or half a month; and from this to the pole they count by the increase of half-months or whole months, the climates ending at the poles where the days are six months long. The climates betwixt the equator and the polar circles are called hour-climates, and those between the polar circles

and the poles are called month-climates. In common language, however, we take the word climate in a very different sense; so that when two countries are said to be in different climates, we understand only that the temperature of the air, seasons, &c. are different.

From the difference in the length and positions of the shadows of terrestrial substances, ancient geographers have given different terms to the inhabitants of certain places of the earth: the reason of which will be easily understood from the following considerations: 1. Since the sun in his apparent annual revolution never removes farther from the equator than 23½ degrees, it follows, that none of those who live without that space, or beyond the tropics, can have the luminary vertical to them at any season of the year. 2. All who live between the tropics have the sun vertical twice a year, though not all at the same time. Thus, to those who live directly under the equator, he is directly vertical in March and September at the time of the equinox. If a place is in 10° north latitude, the sun is vertical when he has 10° north declination, and so of every other place. 3. All who live between the tropics have the sun at noon sometimes north and sometimes south of them. Thus those who live in a place situated in 20° north latitude have the sun at noon to the northward when he has more than 20° north declination, and to the southward when he has less. 4. Such of the inhabitants of the earth as live without the tropics, if in the northern hemisphere, have the sun at noon to the southward of them, but to the northward if in the southern hemisphere.—1. Hence when the sun is in the zenith of any place, the shadow of a man or any upright object falls directly upon the place where they stand, and consequently is invisible; whence the inhabitants of such places were called Ascii, or without shadows. 2. Those who live between the tropics, and have the sun sometimes to the north and sometimes to the south of them, have of consequence their shadows projecting north at some seasons of the year, and south at others, whence they were called Amphiscii, or having two kinds of shadows. 3. Those who live without the tropics have their noon-shadows always the same way, and are therefore called Heteroscii, that is, having only one kind of shadow. If they be in north latitude, the shadows are always turned towards the north, and if in the southern hemisphere, towards the south. 4. When a place is so far distant from the equator that the days are twenty-four hours long,

or longer, the inhabitants were called Periscii, because their shadows turn round them.

Names have likewise been imposed upon the inhabitants of different parts of the earth, from the parallels of latitude under which they live, and their situation with regard to one another. 1. Those who lived at distant places, but under the same parallel, have been called Periæci, that is, living under the same circle. Some writers, however, by the name of Periæci distinguish those who live under opposite points of the same parallel, where the noon of one is the midnight of the other. 2. When two places lie under parallels equally distant from the equator, but in opposite hemispheres, the inhabitants have been called Antæci. These have a similar increase of days and nights, and similar seasons, but in opposite months of the year. According to some, the Antæci are such as live under the same geographical meridian, and have day and night at the same time. 3. If two places be in parallels equally distant from the equator, and in opposite meridians, the inhabitants have been denominated Antipodes, that is, persons having their feet opposite to one another. When two persons are Antipodes, the zenith of the one is the nadir of the other. They have a like elevation of the pole, but it is of different poles; they have also days and nights alike, and similar seasons of the year, but they have opposite hours of the day and night, as well as seasons of the year. Thus, when it is mid-day with us, it is midnight with our Antipodes; when it is summer with us, it is winter with them, &c.

From the various appearances of the sun, and the effects of his light and heat upon different parts of the earth, the division of it into zones has arisen. These are five in number. 1. The torrid zone, lying between the two tropics for the space of 47° of latitude. This is divided into two equal parts by the equator. 2. The two temperate zones lie between the polar circles and the tropics, containing a space of 43° of latitude. And, 3. The two frigid zones lie between the polar circles and the poles. In these last the longest day is never below twenty-four hours; in the temperate zones it is never quite so much, and in the torrid zone it is never above fourteen. The zones are named from the degree of heat they were supposed to be subjected to. The torrid zone was supposed by the ancients to be uninhabitable, on account of its heat; but this is now found to be a mistake, and many parts of the temperate zones are

more intolerable in this respect than the torrid zone itself. Towards the polar circles also these zones are intolerably cold during the winter season. Only a small part of the northern frigid zone, and none of the southern, is inhabited. Some geographers reckoned six zones, dividing the torrid zone into two by the equator.

Beside these, there are other technical terms belonging to geography which it is necessary to explain: some of these have relation to the earth, and others to the water.

A continent is a large portion of the earth, which comprehends several countries that are not separated by any sea; such are Europe, Asia, Africa, and America. An island is a part of the earth which is entirely surrounded by water; as Great Britain. A peninsula is a tract of land almost surrounded with water, and is joined to a continent only by a narrow slip or neck; such is the Morea in Greece. An isthmus, or neck of land, is that part by which a peninsula is joined to a continent, or two continents together; as the isthmus of Suez, which joins Africa to Asia. A promontory, or cape, is a high part of land which stretches into the sea: thus the Cape of Good Hope is a promontory. An ocean is a vast collection of waters surrounding a considerable part of a continent; as the Atlantic. A sea is a smaller collection of waters; as the Black Sea. A gulf is a part of the sea which is nearly surrounded with land; as the gulf of Venice. A bay has a wider entrance than a gulf; as the Bay of Biscay. A strait is a narrow passage that joins two seas; as the Strait of Gibraltar, which joins the Mediterranean to the Atlantic. A lake is a large collection of water entirely surrounded by land, having no visible communication with the sea; as the Windermere, in Cumberland. A river is a large stream of water that has its source from a spring, which keeps constantly running till it falls into some wider river, or into the sea.

In a popular point of view, geography admits of three divisions: 1. The ancient or classical, which describes the state of the earth, not extending farther than the 500th year of the Christian æra. 2. That of the middle ages, which reaches to the fifteenth century, when the discoveries of the Portuguese began to lay broader foundations for this science. 3. Modern geography, the chief object of which is to present the most recent and authentic information concerning the nations and states which divide and diversify the earth. In some instances natural barriers have divided, and continue to

divide, nations; but in general the boundaries are arbitrary, so that the natural geography of a country may be regarded as a sequel to the science, which is chiefly occupied in describing the diversities of nations, and the conditions of the various races of mankind.

The ancients considered the globe under the three grand divisions of Asia, Europe, and Africa. Here the distinctions were arbitrary, as they often included Egypt under Asia, and they had not discovered the limits of Europe toward the north-east. Modern discoveries have added a fourth division, that of America, which exceeding even Asia in size, might have been admitted under two grand and distinct denominations, limited by the isthmus of Darien. Till within these last thirty years it was supposed that a vast continent existed in the south of the globe; but the second navigation of captain Cook dispelled the idea, and demonstrated, that if any continent existed there, it must be in the uninhabitable ice of the south pole. The vast extent of New Holland rewarded the views of enterprise; this, which seems too large to be classed among islands, has been ranked as a fifth division of the globe by various geographers of the present day, and distinguished by the name of *Australasia*, which term, however, includes also the encircling islands.

Of the grand divisions of the earth, Asia has ever been esteemed the most populous; and is supposed to contain five hundred millions of souls, if China, as has been averred by the latest writers, comprises three hundred and thirty millions. The population of Africa may be estimated at thirty millions, of America at twenty millions, and one hundred and fifty millions may perhaps be assigned to Europe.

Modern discoveries have evinced that more than two-thirds of the globe is covered with water, which is contained in hollow spaces, or concavities, more or less large. But the chief convexities or protuberances of the globe consist of elevated uplands, sometimes crowned by mountains, sometimes rather level, as the extensive protuberance of Asia. In either case, long chains of mountains commonly proceed from those chief convexities in various directions, and the principal rivers usually spring from the most elevated grounds.

The grandest concavity of this globe is filled by the Pacific Ocean; occupying nearly half its surface from the eastern shores of New Holland, to the western coast of America, and diversified with seve.

ral groups of islands, which seem in a manner the summits of vast mountains emerging from the waves. This ocean receives but few rivers, the chief being the Amur from Tartary, the Hoan Ho and Kian Ku from China, while the principal rivers of America run towards the east.

Next to this in magnitude is the Atlantic, between the Old and New Continents; and the third is the Indian Ocean. The seas between the arctic and antarctic circles and the poles, have been sometimes styled the Arctic and Antarctic Oceans; but the latter is only a continuation of the Pacific, Atlantic, and Indian Oceans; while the Arctic Sea is partly embraced by continents, and receives many important rivers. Besides these, there are other seas more minute, as the Mediterranean, the Baltic, and others still smaller, till we come by due gradation to inland lakes of fresh water.

The courses of rivers are sometimes marked by oblong concavities, which generally at first intersect the higher grounds, till the declivity becomes more gentle on their approach to their inferior receptacles. But even large rivers are found sometimes to spring from lowland marshes, and wind through vast plains, unaccompanied by any concavity, except that of their immediate course; while on the other hand, extensive vales, and low hollow spaces, frequently occur destitute of any stream. Rivers will also sometimes force a passage where nature has erected mountains and rocks against it, and where the concavity would appear to be in another direction, which the river might have gained with more ease. In like manner, though the chief mountains of Europe extend in a south-easterly and north-westerly direction, yet there are so many exceptions, and such numerous and important variations in other parts of the globe, as to render any attempt at a general theory vain.

From the vast expanse of oceanic waters, arises in the ancient hemisphere, that wide continent, which contains Asia, Europe, and Africa; and in the modern hemisphere, the continent of America, which forms a kind of separate island, divided by a strait of the sea from the ancient continent. In the latter many discoveries of great importance to geography, are of very recent date, and it is not above sixty years since we obtained an imperfect idea of the extent of Siberia and the Russian empire, nor above twenty-five since ample, real, and accurate knowledge of these wide regions began to be diffused. So that, in truth, America may be said to have been discovered by Europeans before many parts of Asia; and of Africa

our knowledge continues imperfect, while the latest observations, instead of diminishing, rather increase our idea of its extent, at least in regard to its insular appendages.

But the grandest division of the ancient continent is Asia, the parent of nations, and of civilization: on the north-east and south, surrounded by the ocean; but on the west, divided by an ideal line from Africa; and from Europe by boundaries not very strongly impressed by the hand of nature. The Russian and the Turkish empires, extending over large portions of both continents, intimately connect Asia with Europe. But for the sake of clearness and precision, geographers retain the strict division of the ancient continent into three parts, which, if not strictly natural, is ethical, as the manners of the Asiatic subjects of Russia, and even of Turkey, differ considerably from those of the European inhabitants of those empires.

CHAP. VI.

SUBTERRANEAN PHÆNOMENA OF THE GLOBE.

It is only the mere surface or solid crust of the globe of which the ingenuity of man has hitherto been able to obtain any degree of knowledge: of the centre, or even the parts below the surface, we are totally ignorant. So far, however, as we have been able to examine into the nature of its contents and structure by means of rivers, ravines, mines, earthquakes, and other causes, it consists of immense masses of rocks and veins; of volcanoes and other caverns; of wells, streams, and peculiar exhalations; of metallic mines and petrified fossils; and of whole towns and forests subverted and in a state of ruins. To each of these we shall direct the reader's attention in the subsequent chapters of the book before us, and nearly in the order in which we have thus enumerated them, and shall at the same time take a glance at whatever else may incidentally occur to us, whether of natural or artificial origin, that from its form, rarity, or any other circumstance, may be an object worthy of general attention.—*Editor*.

CHAP. VII.

ROCKS AND VEINS.

THE stony masses of which the earth, as far as we know it, is composed, are numerous, and they are found laid one above another; so that a rock of one kind of stone is covered by another species of rock, and this by a third, and so on. Now in this superposition of rocks it has been observed, that their situation is by no means arbitrary; every one occupies a determinate place, so that they follow each other in regular order from the deepest part of the earth's crust, which has been examined, to the very surface. Thus there are two things respecting rocks which claim our attention; namely, their composition, and their relative situation. But besides the rocks which constitute almost the whole of the earth's crust, there are masses which must also be considered. These traverse the rocks in a different direction, and are known by the name of *veins*, as if the rocks had split asunder in different places from top to bottom, and the chasm had been afterwards filled up with the matter which constitutes the vein.

Thus it appears, that when we consider compound minerals, or rocks, the subject naturally divides itself into three parts; namely, 1. The structure of rocks; 2. The situation of rocks; 3. Veins. These shall form the subject of the three following sections.

SECT. I.—*Of the Structure of Rocks.*

Rocks may be divided into two classes; viz.

I. Simple, or composed of one mineral substance.

II. Compound, or composed of more than one mineral substance.

Compound rocks are of two kinds; namely,

I. Cemented; composed of grains agglutinated by a cement, as *sand-stone.*

II. Aggregated; composed of parts connected together without a cement, as *granite.*

The aggregated rocks are likewise of two kinds; namely,

I. Indeterminate.

Only one instance of this kind of aggregation has hitherto occurred, namely in the *older serpentine*, where limestone and serpentine are so conjoined, that it is difficult to say which predominates.

II. Determinate.

The determinate are either, I. Single aggregated; or, II. Double aggregated.

There are four kinds of single aggregated rocks; namely,

1. Granular; composed of grains whose length, breadth, and thickness are nearly alike, and which are of contemporaneous formation. As *granite, sienite.*
2. Slaty; composed of plates laid above each other; as *mica slate.*
3. Porphyritic; composed of a compact ground, containing in it crystals which appear to have been deposited at the time the rock was formed; as *common porphyry.*
4. Amygdaloidal; composed of a compact ground, containing in it vesicles which appear to have been afterwards filled up; as *amygdaloid.*

There are five kinds of double aggregated rocks; namely,

1. Granular slaty; composed of slaty masses laid on each other. Every individual slate is composed of grains cohering together; or it is slaty in the great, and granular in the small; a *gneiss.*
2. Slaty granular; composed of large granular masses cohering together; each grain is composed of plates; or the rock is granular in the great, and slaty in the small; as *topaz rock.*
3. Granular porphyritic; granular in the small, and porphyritic in the great; as *granite, greenstone* frequently.
4. Slaty porphyritic; slaty in the small, porphyritic in the great; as *mica slate* frequently.
5. Porphyritic and amygdaloidal; a mass porphyritic and amygdaloidal at the same time; as *amygdaloid* and *basalt* frequently.

Such are the different kinds of structures of rocks hitherto observed and described. The following Table will give the reader a synoptical view of these different kinds of structure:

I. Simple rocks

II. Compound rocks

A. Cemented

B. Aggregated
 a. Indeterminate
 b. Determinate
  I. Single
   1. Granular
   2. Slaty
   3. Porphyritic
   4. Amygdaloidal
  II. Double
   1. Granular slaty
   2. Slaty granular
   3. Granular porphyritic
   4. Slaty porphyritic
   5. Porphyritic and amygdaloidal

SECT. II.—*Of the relative Situation of Rocks.*

The rocky masses, or rocks, hitherto observed, amount to about sixty. Of these rocks, variously placed over each other, the whole crust of the earth is composed, to the greatest depth that the industry of man has been able to penetrate; and with respect to each other, they occupy for the most part a determinate situation, which holds invariably in every part of the earth. Thus lime-stone is no where found under granite, but always above it. Were we to suppose every particular rock, or layer, which constitutes a part of the earth's surface to be extended round the whole earth, and to be wrapped round the central nucleus, like the coat of an onion, in that case every rock would be constantly found: one species would be always lowest or nearest the centre; another species would uniformly rest upon this first; a third upon the second, and so on. Now, though the rocks do not in reality extend round the earth in this uninterrupted manner; though, partly from the inequality of the nucleus on which they rest, partly from their own inequality of thickness in different places, and partly from other causes, the continuity is often interrupted; yet still we can trace enough of it to convince us that the rocks which constitute the earth's crust, considered in a great scale, are every where the same, and that they invariably occupy the same situation with respect to each other. Werner has therefore chosen this relative situation as the basis of his classification of rocks. He divides them into five

classes. The first class consists of those rocks which, if we were to suppose each layer to be extended over the whole earth, would in that case lie lowest, or nearest the centre of all the rocks which we know to be covered by all the other rocks. The second class consists of those rocks which in that case would be immediately above the first class and cover them. The third class would cover the second in the same manner; the fourth the third; and the fifth would be uppermost of all, and constitute the immediate surface of the earth. The first class of rocks are covered by all the rest, but never themselves lie over any other. The others lie in order over each other. These grand classes of rocks he has denominated *formations*, and distinguished them by the following specific names:

I. Primitive formations
II. Transition formations
III. Floetz, or horizontal formations
IV. Alluvial formations
V. Volcanic

The primitive formations are of course the lowest of all, and the alluvial constitute the very surface of the earth; for the volcanic, as is obvious, are confined to particular points. Not that the primitive are always at a great depth under the surface, very often they are at the surface, or even constitute mountains. In such cases, the other classes of formations are wanting altogether. In like manner the transition, and other formations, may each in its turn occupy the surface, or constitute the mass of a mountain. In such cases, all the subsequent formations which ought to cover them are wanting in that particular spot.

Each of these grand classes of formations consists of a greater or smaller number of rocks, which occupy a determinate position with respect to each other, and which, like the great formations themselves, may often be wanting in particular places. Let us take a view of the rocks which compose all these different formations.

Class I. *Primitive Formations.* The rocks which constitute the primitive formations are very numerous. They have been divided therefore into seven sets, which constitute as many primitive formations, and are distinguished each by the name of that particular

SLATE QUARRY IN LONG-SLE-DALE, WESTMORELAND.

classes. The first class consists of those rocks which, if we were to suppose each layer to be extended over the whole earth, would in that case lie lowest, or nearest the centre of all the rocks which we know to be covered by all the other rocks. The second class consists of those rocks which in that case would be immediately above the first class and cover them. The third class would cover the second in the same manner; the fourth the third; and the fifth would be uppermost of all, and constitute the immediate surface of the earth. The first class of rocks are covered by all the rest, but never themselves lie over any other. The others lie in order over each other. These grand classes of rocks he has denominated *formations,* and distinguished them by the following specific names:

I. Primitive formations
II. Transition formations
III. Floetz, or horizontal formations
IV. Alluvial formations
V. Volcanic

The primitive formations are of course the lowest of all, and the alluvial constitute the very surface of the earth; for the volcanic, as is obvious, are confined to particular points. Not that the primitive are always at a great depth under the surface, very often they are at the surface, or even constitute mountains. In such cases, the other classes of formations are wanting altogether. In like manner the transition, and other formations, may each in its turn occupy the surface, or constitute the mass of a mountain. In such cases, all the subsequent formations which ought to cover them are wanting in that particular spot.

Each of these grand classes of formations consists of a greater or smaller number of rocks, which occupy a determinate position with respect to each other, and which, like the great formations themselves, may often be wanting in particular places. Let us take a view of the rocks which compose all these different formations.

Class I. *Primitive Formations.* The rocks which constitute the primitive formations are very numerous. They have been divided therefore into seven sets, which constitute as many primitive formations, and are distinguished each by the name of that particular

rock which constitutes the greatest proportion of the formation. These seven sets of primitive formations are the following:

1. Granite	{ 5. Newest primitive porphyry
2. Gneiss	{ 6. Sienite
3. Mica-slate	7. Newer serpentine.
4. Clay-slate	

The granite is the undermost, and the sienite the uppermost of the primitive formations. Granite is scarcely mixed with any other rock; but in gneiss, mica-slate, and clay-slate, there occur beds * of old porphyry, primitive trap, primitive lime-stone, old serpentine, quartz rock. For that reason these rocks are said to constitute formations subordinate to gneiss, mica-slate, and clay-slate. Gypsum occurs in beds in mica-slate, and old flint-slate occurs in the same way in clay-slate. Hence they constitute formations subordinate to mica and clay-slate. Thus, besides the seven principal primitive formations, there occur seven subordinate formations, interspersed through the second, third, and fourth formations; and topaz rock, which lies over gneiss and under clay-slate, must be added to the list: so that the primitive formations altogether amount to fifteen.

If we suppose the nucleus of the earth to have been first formed, and the formations to have been afterwards deposited in succession upon this nucleus, it will follow that the lowest formation is the oldest, and that the formations are newer and newer according as they approach the surface. This supposition accounts for some of the names given to the primitive formations. That porphyry, for example, is considered as the oldest, which lies lowest down in the series of formations, and those formations of porphyry which lie nearer the surface are considered as newer. Granite, of course, according to this way of speaking, is the oldest formation of all, while the alluvial are the newest of all. The following Table exhibits a synoptical view of the primitive formations:

* When a mountain is composed of layers of the same kind of stone, it is said to be stratified; but when the layers are of different kinds of stone, it is said to be composed of beds.

Principal.	Subordinate.
1. Granite	
	6. Older porphyry
	7. Primitive trap
2. Gneiss	8. Primitive lime-stone
3. Mica-slate	9. Older serpentine
4. Topaz rock	10. Quartz
5. Clay-slate	11. Gypsum
	12. Older flint-slate
13. Newer porphyry	
14. Sienite	
15. Newer serpentine.	

Class II. *Transition Formations.* Having described the primitive formations, let us now proceed to the second great class, the transition, which lie immediately over them. These are by no means so numerous, since they consist only of four sets; namely,

1. Grey wacke
2. Transition lime-stone
3. Transition trap
4. Transition flint-slate.

They all alternate with each other, sometimes one, sometimes another being undermost, except one bed of transition lime-stone, which seems always to rest upon the primitive formations, and may therefore be considered as the oldest of the transition formations.

It is in the transition rocks that petrifactions first make their appearance; and it deserves particular attention that they always consist of species of corals and zoophytes, which do not at present exist, and which therefore we may suppose extinct. The vegetable petrifactions are likewise the lowest in that kingdom, such as ferns, &c. This remarkable circumstance has induced Werner to conclude, that the transition rocks were formed after the earth contained organic beings. Hence the name *transition*, which he has imposed, as if they had been formed when the earth was passing from an uninhabited to an inhabited state. The date of their formation is conceived to be very remote, since the petrifactions which they con-

tain are the remains of animal and vegetable species now extinct. It is in the transition rocks, too, that carbonaceous matter makes its firm appearance in any notable quantity.

Class III. *Floetz Formations.* The next grand class of formations have received the name of *floetz,* because they lie usually in beds much more nearly horizontal than the preceding. When not covered by a succeeding formation, they form hills which do not rise to the same height as the primitive or transition. They contain abundance of petrifactions; and these much more various in their nature than those which occur in the transition formations, consisting of shells, fish, plants, &c. indicating that they were formed at a period when organized beings abounded.

The floetz formations lie immediately over the transition. They comprehend a great number of individual formations, each of which affects a particular situation. The following table exhibits a view of these different formations in the order of their position, as far as is known.

1. Old red sand-stone
2. First floetz lime-stone
3. First floetz gypsum with rock salt
4. Variegated sand-stone
5. Second floetz gypsum
6. Second floetz or shell lime-stone

* * *

7. Third sand-stone or free-stone

* * *

8. Chalk

* * *

9. Independent coal
10. Floetz trap.

The position of the two formations separated from the rest, and from each other, by asterisks, has not been ascertained in a satisfactory manner. The last formation, the floetz trap, lies over the rest, pretty much as the newer porphyry and sienite do over the older primitive formations.

Class IV. *Alluvial Formations.* The alluvial formations consti-

tute the great mass of what is actually the earth's surface. They have been formed by the gradual action of rain and river water upon the other formations, and may be considered as very recent formations, or rather as deposites, the formation of which is still constantly going on. They may be divided into two kinds: those deposited in the valleys of mountainous districts, or upon the elevated plains which often occur in mountains; and those deposited upon flat land.

The first kind consist of sand, gravel, &c. which constituted the more solid parts of the neighbouring mountains, and which remained when the less solid parts were washed away. They sometimes contain ores (particularly gold and tin) which existed in the neighbouring mountains. Sometimes the alluvial soil is washed, in order to separate these ores. On mountain plains there occur also beds of loam.

The second kind of alluvial deposit, or that which occupies the flat land, consists of loam, clay, sand, turf, and calctuff*. Here also occur earth and brown coal (in this mineral amber is found), wood coal, bituminous wood, and bog iron ore. The sand contains some metals, among others gold. The calctuff is a chemical deposit and extends widely. It contains plants, roots, moss, bones, &c. which it has encrusted. The clay and sand often contain petrified wood, and likewise skeletons of quadrupeds.

Class V. *Volcanic Formations.* The volcanic formations are of two kinds; namely, the *pseudo-volcanic* and the *true volcanic.*

The pseudo-volcanic consist of minerals altered in consequence of the burning of beds of coal situated in their neighbourhood. Porcelain jasper, earth slag, burnt clay, columnar clay-iron stone, and perhaps also polishing slate, are the minerals which have been thus altered.

The real volcanic minerals are those which have been thrown out of the crater of a volcano. They are of three kinds; 1. Those substances which, having been thrown out from time to time, have formed the crater of the mountain: 2. Those which have been thrown out of the crater in a stream, and rolled down the mountain; they constitute lavas: 3. The water which is occasionally thrown out of volcanoes, containing ashes and other light sub-

* Stalactitic or calcareous tufa.—*Editor.*

stances, gradually evaporating, leaves the earthy matter behind it; this substance constitutes volcanic tuff.

SECT. III.—*Of Veins.*

Veins are mineral repositories which cut through the strata or beds of which a mountain is composed, and which are filled with substances more or less different from the rocks through which they pass. We shall have a very distinct notion of veins, if we suppose that the mountains in which they occur were split by some means or other, and that the rifts thus formed were filled up by the matter which constitutes veins. They are distinguished from beds by their direction, which is either perpendicular to the stratifications, or at least forms an angle with it.

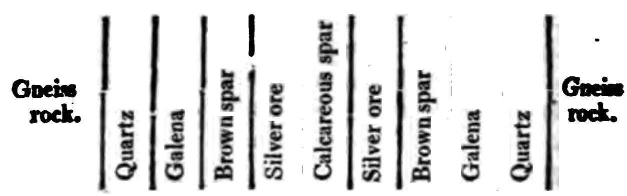
Sometimes the strata through which veins pass are merely separated from each other; so that if we cut through the vein we find the same strata of the rock on both sides of it: but sometimes also the corresponding strata on one side are lower than on the other, as if the portion of the rock on one side of the vein had sunk a little, while the portion on the other side kept its original position. In such cases, the side of the rock against which the vein leans, or the floor of the vein, has always its strata highest up; whilst the strata of the portion of rock which leans over the vein, or the roof of the vein, are always lowest. So that this is the portion which appears to have sunk. Such a change of position in the strata is known in this country by the name of a *shift*.

In considering veins, there are two circumstances which claim our attention: namely, 1. The shape of veins; and, 2. The substances with which they are filled.

1. All those mineralogists who have had the best opportunity of examining the shape of veins with correctness, agree in representing them as widest above, and as gradually diminishing in size as they deepen, till at last they terminate in a point, exactly as if they had been originally fissures. This is the account of Oppel, of Werner, and indeed of all those writers who have been professionally engaged in superintending mines. Sometimes, indeed, veins widen in different parts of their course, and afterwards contract again to their former size; but more commonly they continue diminishing gradually to their extremity.

2. Sometimes these veins are either partially or entirely empty.

In that case they are denominated *fissures*; but most commonly they are filled with a matter more or less different from the rock through which they pass. Sometimes the vein is filled up with one species of mineral. Thus we have veins of calcareous spar, of quartz, &c.; but when it is of any size, we frequently find a variety of substances: these are disposed in regular layers always parallel to the sides of the vein, and they follow in their position a very regular order. One species of mineral constitutes the centre of the vein: on each side of this central bed the very same layers occur in the same order from the centre to the side of the vein. To give an example; the vein Gregorius, at Freyberg, is composed of nine layers or beds. The middle of the vein consists of a layer of calcareous spar; on each side of this is a layer consisting of various ores of silver mixed together; on each side of this a layer of brown spar; on each side of this a layer of galena; on each side of this again, and contiguous to the side of the vein, is a layer of quartz. The following sketch will give the reader some notion of the relative position of these layers:



Sometimes the number of layers of which a vein is composed greatly exceeds this. Werner describes one in the district of Freyberg, in which the middle layer is calcareous spar, having on each side of it no less than thirteen layers arranged in the very same order*.

Almost every mineral substance which occurs in the mass of rocks has been found in veins. We sometimes find them filled with different well-known stony bodies. Thus veins of granite, porphyry, lime-stone, basalt, wacke, green-stone, &c. are not uncommon †; veins of quartz, clay, felspar, &c. are equally common.

* Nouvelle Theorie de la Formation des Filons, p. 100.

† Werner, Nouvelle Theorie, p. 93.

Pit-coal and common salt, and almost all the metals, likewise occur in veins. Some veins are filled with water-worn pebbles, as one observed by Werner at Joachimstahl *. Some are filled with loam †. Nay, they even sometimes contain petrifactions. Thus the Baron de Born describes a petrified popites which he saw in a compact cinnabar vein in Hungary; and Mr. de Schlottheim communicated an account of a still more remarkable appearance of the same kind to Werner. In a calcareous mountain in Thuringia, there occur veins of marl five or six inches thick, containing petrifactions differing altogether from those which are found in the lime-stone. The petrifactions found in the marl are, cornua ammonis, terebrates, and turbinites; while those that occur in the lime-stone rock are trochites. Beds of the marl occur in the neighbourhood; and these beds contain the same petrifactions that are found in the veins ‡.

3. It is very common to find veins crossing each other in the same rock. When that happens, one of the veins may be traced passing through the other without any interruption, and cutting in two, while the other always separates, and disappears at the point of crossing.

4. Such is a short sketch of the most remarkable phænomena respecting veins. Werner supposes that they were originally fissures formed in the rocks, and that they were all gradually filled by minerals depositsd slowly from above, while the rocks in which they occur were covered by water, and that they were filled at the same time that the different formations were deposited. This theory he has supported in his book on Veins, by a very complete enumeration of all the circumstances respecting their structure and appearances. He has shown that they resemble fissures very exactly in their shape and direction; and that as they contain petrifactions and minerals altered by the action of water, they must of necessity have been filled from above.

Veins of course, according to this theory, are newer than the rocks in which they occur; and when two veins cross, that is obviously the newest which traverses the other without interruption, as the fissures constituting the second vein must have been formed after

* Werner, Nouvelle Theorie, p. 81.

† Ibid. p. 82.

‡ Ibid. p. 88.

the first vein was filled up. When different veins contain the same minerals arranged in the same order, he conceives that they were filled at the same time, and says that such veins belong to the same formation. When they differ in these respects, they belong to different formations. From the position of the respective veins with respect to each other, he deduces their relative age; and from this draws inferences respecting the relative age of the different mineral substances that occur in veins similar to the inferences drawn respecting the age of the rocks which constitute the grand classes of formations.

[*Thomson's System of Chemistry, Vol. IV. occasionally altered.*]

CHAP. VIII.

VOLCANOES, EARTHQUAKES, AND SUBTERRANEAN FIRES.

That fires to an enormous extent, and produced by various causes, may exist at different depths beneath the surface of the earth, must, we think, be clear to every one who has attentively perused the preceding chapters of the present book: and we have much reason to believe, from a very curious series of experiments lately conducted by Sir James Hall, that, where the substances in which such fires occur lie profound, and are surmounted by a very deep and heavy super-incumbent pressure; and, more especially, where they, at the same time, contain large portions of elastic gasses; the effects of such fires will be prodigiously greater, and more diversified, than where these circumstances are absent.

Earthquakes and volcanoes may be reckoned, for the most part, among the most powerful and extraordinary of these effects; and as resulting from those chemical changes which the agency of fire principally produces in the interior of the solid crust of the globe. They have, probably, little further connection with electricity than as causes that occasionally destroy the equilibrium; for although some authors have inferred, from the great velocity with which the

shock of an earthquake is transmitted from place to place, that its nature must be electrical, yet others have, with greater probability, attributed the rapid succession of the effects to the operation of a single cause, acting like subterranean heat, at a great distance below the earth's surface. There are, however, some circumstances which indicate such a connexion between the state of the atmosphere and the approach of an earthquake, as cannot easily be explained by any hypothesis.

The shocks of earthquakes, and the eruptions of volcanoes, are in all probability modifications of the effects of one common cause; the same countries are liable to both of them; and where the agitation produced by an earthquake extends further than there is any reason to suspect a subterraneous commotion, it is probably propagated through the earth nearly in the same manner as a noise is conveyed through the air. Volcanoes are found in almost all parts of the world, but most commonly in the neighbourhood of the sea; and especially in small islands; for instance, in Italy, Sicily, Iceland, Japan, the Caribbees, the Cape Verd islands, the Canaries, and the Azores: there are also numerous volcanoes in Mexico and Peru, especially Pichincha and Cotopaxi. The subterraneous fires, which are continually kept up in an open volcano, depend perhaps in general on sulphureous combinations and decompositions, like the heating of a heap of wet pyrites, or the union of sulphur and iron filings: but in other cases they may perhaps approach more nearly to the nature of common fires. A mountain of coal has been burning in Siberia for almost a century, and must probably have undermined in some degree the neighbouring country. The immediate cause of an eruption appears to be very frequently an admission of water from the sea, or from subterraneous reservoirs; it has often happened that boiling water has been discharged in great quantities from a volcano; and the force of steam is perhaps more adequate to the production of violent explosions, than any other power in nature. The consequence of such an admission of water, into an immense collection of ignited materials, may in some measure be understood, from the accidents which occasionally happen in founderies: thus a whole furnace of melted iron was a few years ago dissipated into the air in Colebrook Dale, by the effect of a flood which suddenly overflowed it.

The phænomena of earthquakes and volcanoes are amply illustrated

him, while he was involved in a shower of small pumice stones and ashes, and in a cloud of smoke. The force of the explosions was so great, that doors and windows were thrown open by them at the distance of several miles: the stream of lava was in some places two miles broad, and 60 or 70 feet deep; it extended about six miles from the summit of the mountain, and remained hot for several weeks. In 1794 a still more violent eruption occurred: it was expected by the inhabitants of the neighbourhood, the crater being nearly filled, and the water in the wells having subsided. Showers of immense stones were projected to a great height; and ashes were thrown out so copiously, that they were very thick at Taranto, 250 miles off; some of them also were wet with salt water. A heavy noxious vapour, supposed to be carbonic acid, issued in many places from the earth, and destroyed the vineyards in which it was suffered to remain stagnant. A part of the town of Torre del Greco was overwhelmed by a stream of lava, which ran through it into the sea; yet nothwithstanding the frequency of such accidents, the inhabitants had so strong a predilection for their native spot, that they refused the offer of a safer situation for rebuilding their houses.

[*Editor. Young, Nat. Phil. Della Torre, Istoria del Vesuvio.*]

CHAP. IX.

ERUPTIONS OF VESUVIUS.

THERE is no volcanic mountain in Europe, whose desolating paroxysms have been so fatally experienced, and so accurately transmitted to us, as those of Vesuvius.

This mountain is well known to constitute one of the natural wonders of the kingdom of Naples. Like Parnassus, it has been said to consist of two summits, one of which, situated in a westward direction, is called by the natives Somma; and the other, running in a southern line, Proper Vesuvius, or Vesuvio; and it is this last alone which emits fire and smoke. The two hills or summits are separated by a valley of about a mile in length, and peculiarly fertile

INTERIOR VIEW OF THE CRATER OF MOUNT VESUVIUS.

in its productions. The eruptions of this mountain have been numerous in almost every age of the Christian æra; and on many occasions prodigiously destructive. From the numerous narrations to which they have given rise, we shall confine ourselves to those that are most awful or interesting.

SECT. I.—*Destruction of Pompeii and Herculaneum.*

THE earliest and one of the most fatal eruptions of Vesuvius that occurs to us in history, took place in the year 79 of the Christian æra, and the first of the reign of Titus. All Campania was alarmed by its violence, and the country was devastated in every direction to a very great distance; numerous towns with the whole of their inhabitants were consumed, and among the rest, the elegant cities of Pompeii and Herculaneum, the ruins of which, after having been utterly overwhelmed and lost for more than sixteen centuries, were at length traced out by accident; and, so far as they relate to the latter, have been explored to a considerable extent. The wreck of Herculaneum was discovered in 1739, and was rendered accessible by a well in the course of the ensuing year.

Pompeii had suffered severely from an earthquake, sixteen years before the eruption of 79, but had been rebuilt and embellished with several stately edifices; especially with a magnificent theatre, in which the people were assembled, and intent upon the spectacle, when this tremendous visitation burst upon them, swallowing up the city by an earthquake, and overcovering its site to a considerable depth with the fiery materials that were thrown forth from the mouth of the crater. The cities of Puteoli and Cumæ were also greatly damaged, partly by the concussions, and partly by the burning ashes, which last, according to the concurrent assertion of ancient historians, extended to Africa, Egypt and Syria, and at Rome turned the day suddenly into night, to the consternation of the inhabitants. It was during this emption, that the elder Pliny fell a victim to suffocation, the poet Cesius Bassus and his household were consumed by the flames, and Agrippa, son of Claudius Felix, the well-known governor of Judæa, and of Drusilla, daughter to Agrippa, the last king of the Jews, perished in his youth as we are told by Josephus; though the passage of this writer in which he refers for a more particular account of his death, is no longer extant.

The earliest of the eruptions of Vesuvius of which we have any narrative, is so exquisitely and impressively related by the younger Pliny, in two letters to his friend Tacitus the historian, that it has been rendered almost as celebrated, from this fine and touching description, as on account of the extent of the calamity itself. But though this description is the earliest, we are not to conclude that no eruption had ever taken place antecedently. Neither Pliny nor Tacitus hint at any thing to this effect, nor express the smallest surprise at the phænomenon, which they undoubtedly would have done, had it been the first of the kind. One of the earliest we meet with in history, next to that narrated by Pliny, is comparatively in our own times; it occurred in 1538, and formed the crater near Pozzicoli, which has received the name of *Monte Nuovo*. Curiosity led many persons to look into this crater a few days after the eruption had ceased, when twenty of the rashest and most daring were destroyed by a sudden explosion of smoke, stones, and ashes. The next of which we have any document, took place in 1631, and is described by Antonio Santorelli, as also by the Abbate Braccini: during which the sea, as in the eruption of 79, retreated from the coast. The next memorable eruption in the order of time, is that described by Valetta in 1707: since which period, accounts of not fewer than ten others have been published in the Philosophical Transactions, for nearly half of which the world is greatly indebted to the assiduity and intrepidity of Sir William Hamilton. Besides these, we have also an account of an eruption in 1717, by bishop Berkeley, and of another in 1737 by Dr. Serao, published the same year at Naples.

The description of Pliny is as follows; and the two letters that contain it are numbered sixteen and twenty in the sixth book of his epistolary collection.

"TO TACITUS.

"YOUR request that I would send you an account of my uncle's death, in order to transmit a more exact relation of it to posterity, deserves my acknowledgments; for if this accident shall be celebrated by your pen, the glory of it I am well assured will be rendered for ever illustrious. And notwithstanding he perished by a misfortune, which, as it involved at the same time a most beautiful country in ruins, and destroyed so many populous cities, seems to promise him

an everlasting remembrance; notwithstanding he has himself composed many and lasting works; yet I am persuaded the mentioning of him in your immortal writings will greatly contribute to eternize his name. Happy I esteem those to be, whom Providence has distinguished with the abilities either of doing such actions as are worthy of being related, or of relating them in a manner worthy of being read; but doubly happy are they who are blessed with both these uncommon talents; in the number of which my uncle, as his own writings and your history will evidently prove, may justly be ranked. It is with extreme willingness, therefore, that I execute your commands; and should indeed have claimed the task, if you had not enjoined it. He was at that time with the fleet under his command at Misenum*. On the 23d of August, about one in the afternoon, my mother desired him to observe a cloud which appeared of a very unusual size and shape. He had just returned from taking the benefit of the sun†, and after bathing himself in cold water, and taking a slight repast, had retired to his study: he immediately arose and went out upon an eminence from which he might more distinctly view this very uncommon appearance. It was not at that distance discernible from what mountain this cloud issued, but it was found afterwards to ascend from mount Vesuvius‡. I cannot give you a more exact description of its figure than by resembling it to that of a pine-tree, for it shot up a great height in the form of a trunk, which extended itself at the top into a sort of branches; occasioned, I imagine, either by a sudden gust of air that impelled it, the force of which decreased as it advanced upwards; or the cloud itself being pressed back again by its own weight, expanded in this manner. It appeared sometimes bright, and sometimes dark and spotted, as it was either more or less impregnated with earth and cinders. This extraordinary phenomenon excited my uncle's philosophical curiosity to take a nearer view of it. He ordered a light vessel to be got ready, and gave me the liberty, if I thought proper, to attend him. I rather chose to continue my studies; for, as it happened, he had given me

* In the gulf of Naples.

† The Romans used to lie or walk naked in the sun, after anointing their bodies with oil, which was esteemed as greatly contributing to health, and therefore daily practised by them.

‡ About six miles distant from Naples.—This dreadful eruption happene A. D. 79, in the first year of the emperor Titus.

an employment of that kind. As he was coming out of the house, he received a note from Rectina the wife of Bassus, who was in the utmost alarm at the imminent danger which threatened her; for her villa being situated at the foot of mount Vesuvius, there was no way to escape but by sea; she earnestly intreated him therefore to come to her assistance. He accordingly changed his first design, and what he began with a philosophical, he pursued with an heroical turn of mind. He ordered the galleys to put to sea, and went himself on board with an intention of assisting not only Rectina, but several others: for the villas stand extremely thick upon the beautiful coast. When hastening to the place from which others fled with the utmost terror, he steered his direct course to the point of danger, and with so much calmness and presence of mind, as to be able to make and dictate his observations upon the motion and figure of that dreadful scene. He was now so nigh the mountain that the cinders, which grew thicker and hotter the nearer he approached, fell into the ships, together with pumice-stones, and black pieces of burning rock; they were likewise in danger not only of being a-ground by the sudden retreat of the sea, but also from the vast fragments which rolled down from the mountain, and obstructed all the shore. Here he stopped to consider whether he should return back again, to which the pilot advising him; "Fortune," said he, "befriends the brave; carry me to Pomponianus." Pomponianus was then at Stabiæ*, separated by a gulf which the sea, after several insensible windings, forms upon that shore. He had already sent his baggage on board; for though he was not at that time in actual danger, yet being within the view of it, and indeed extremely near, if it should in the least increase, he was determined to put to sea as soon as the wind should change. It was favourable, however, for carrying my uncle to Pomponianus, whom he found in the greatest consternation: he embraced him with tenderness, encouraging and exhorting him to keep up his spirits; and the more to dissipate his fears, he ordered, with an air of unconcern, the baths to be got ready; when, after having bathed, he sat down to supper with great cheerfulness, or at least (what is equally heroic) with all the appearance of it. In the mean while the eruption from mount Vesuvius flamed out in several places with much violence, which the darkness of the night

* Now called *Castel à Mar di Stabia*, in the gulf of Naples.

contributed to render still more visible and dreadful. But my uncle, in order to soothe the apprehensions of his friend, assured him it was only the burning of the villages, which the country people had abandoned to the flames; after this he retired to rest, and it is most certain he was so little discomposed as to fall into a deep sleep; for being pretty fat, and breathing hard, those who attended without actually heard him snore. The court which led to his apartment being now almost filled with stones and ashes, if he had continued there any time longer, it would have been impossible for him to have made his way out; it was thought proper therefore to awaken him. He got up, and went to Pomponianus and the rest of his company, who were not unconcerned enough to think of going to bed. They consulted together whether it would be most prudent to trust to the houses, which now shook from side to side with frequent and violent concussions; or fly to the open fields, where the calcined stones and cinders, though light indeed, yet fell in large showers, and threatened destruction. In this distress they resolved for the fields, as the less dangerous situation of the two; a resolution which, while the rest of the company were hurried into it by their fears, my uncle embraced upon cool and deliberate consideration. They went out then, having pillows tied upon their heads with napkins; and this was their whole defence against the storm of stones that fell round them. Though it was now day every where else, with them it was darker than the most obscure night, excepting only what light proceeded from the fire and flames. They thought proper to go down farther upon the shore, to observe if they might safely put out to sea, but they found the waves still run extremely high and boisterous. There my uncle having drunk a draught or two of cold water, threw himself down upon a cloth which was spread for him, when immediately the flames and a strong smell of sulphur, which was the forerunner of them, dispersed the rest of the company and obliged them to arise. He raised himself up with the assistance of two of his servants, and instantly fell down dead; suffocated, as I conjecture, by some gross and noxious vapour, having always had weak lungs, and frequently subjected to a difficulty of breathing. As soon as it was light again, which was not till the third day after this melancholy accident, his body was found entire, and without any marks of violence upon it, exactly in the same

posture that he fell, and looking more like a man asleep than dead. During all this time my mother and I, who were at Misenum—But as this has no connection with your history, so your enquiry went no farther than concerning my uncle's death; with that therefore I will put an end to my letter: suffer me only to add, that I have faithfully related to you what I was either an eye-witness of myself, or received immediately after the accident happened, and before there was time to vary the truth. You will choose out of this narrative such circumstances as shall be most suitable to your purpose; for there is a great difference between what is proper for a letter, and an history; between writing to a friend, and writing to the public. Farewel.

TO CORNELIUS TACITUS.

The letter which, in compliance with your request, I wrote to you concerning the death of my uncle, has raised, it seems, your curiosity to know what terrors and dangers attended me while I continued at Misenum; for there, I think, the account of my former broke off:

> Though my shock'd soul recoils, my tongue shall tell.

My uncle having left us, I pursued the studies which prevented my going with him, till it was time to bathe; after which I went to supper, and from thence to bed, where my sleep was greatly broken and disturbed. There had been for many days before some shocks of an earthquake, which the less surprised us as they are extremely frequent in Campania; but they were so particularly violent that night, that they not only shook every thing about us, but seemed indeed to threaten total destruction. My mother flew to my chamber, where she found me rising in order to awaken her. We went out into a small court belonging to the house, which separated the sea from the buildings. As I was at that time but eighteen years of age, I know not whether I should call my behaviour in this dangerous juncture, courage or rashness; but I took up Livy, and amused myself with turning over that author, and even making extracts from him, as if all about me had been in full security. While we were in this posture, a friend of my uncle's, who was just come from Spain to pay him a visit, joined us, and observing me sitting by my mother with a book in my hand, greatly condemned her calmness, at the same

time that he reproved me for my careless security: nevertheless I still went on with my author. Though it was now morning, the light was exceedingly faint and languid; the buildings all around us tottered, and though we stood upon open ground, yet as the place was narrow and confined, there was no remaining there without certain and great danger; we therefore resolved to quit the town. The people followed us in the utmost consternation, and (as to a mind distracted with terror, every suggestion seems more prudent than its own) pressed in great crowds about us in our way out. Being got at a convenient distance from the houses, we stood still in the midst of a most dangerous and dreadful scene. The chariots which we had ordered to be drawn out were so agitated backwards and forwards, though in the open fields, that we could not keep them steady, even by supporting them with large stones. The sea seemed to roll back upon itself, and to be driven from its banks by the convulsive motion of the earth; it is certain at least the shore was considerably enlarged, and several sea-animals were left upon it. On the other side, a black and dreadful cloud bursting with an igneous serpentine vapour, darted out a long train of fire, resembling flashes of lightning, but much larger. Upon this, our Spanish friend, whom I mentioned above, addressing himself to my mother and me with great warmth and earnestness: "If your brother and your uncle," said he, "is safe, he certainly wishes you may be so too; but if he perished, it was his desire, no doubt, that you might both survive him: why therefore do you delay your escape a moment?" We could never think of our own safety, we said, while we were uncertain of his. Hereupon our friend left us, and withdrew from the danger with the utmost precipitation. Soon afterwards the cloud seemed to descend, and cover the whole ocean; as, indeed, it entirely hid the island of Caprea *, and the promontory of Misenum. My mother strongly conjured me to make my esscape at any rate, which, as I was young, I might easily do: as for herself, she said, her age and corpulency rendered all attempts of that sort impossible; however, she would willingly meet death, if she could have the satisfaction of seeing that she was not the occasion of mine. But I absolutely refused to leave her, and taking her

* An island near Naples, now called Capri.

by the hand, I led her on; she complied with great reluctance, and not without many reproaches to herself for retarding my flight. The ashes now began to fall upon us, though in no great quantity. I turned my head, and observed behind us a thick smoke, which came rolling after us like a torrent. I proposed, while we had yet any light, to turn out of the high road, lest we should be pressed to death in the dark by the crowd that followed us. We had scarce stepped out of the path, when a darkness overspread us, not like that of a cloudy night, or when there is no moon, but of a room when it is shut up and all the lights are extinct. Nothing then was to be heard but the shrieks of women, the screams of children, and the cries of men; some calling for their children, others for their parents, others for their husbands, and only distinguishing each other by their voices; one lamenting his own fate, another that of his family; some wishing to die from the very fear of dying, some lifting up their hands to the gods; but the greater part imagining that the last and eternal night was come, which was to destroy both the gods and the world together*. Among these there were some who augmented the real terrors by imaginary ones, and made the frighted multitude falsely believe that Misenum was actually in flames. At length a glimmering light appeared, which we imagined to be rather the forerunner of an approaching burst of flames (as in truth it was) than the return of day; however, the fire fell at a distance from us: then again we were immersed in thick darkness, and a heavy shower of ashes rained upon us, which we were obliged every now and then to shake off, otherwise we should have been crushed and buried in the heap. I might boast, that during all this scene of horror, not a sigh or expression of fear escaped from me, had not my support been founded in that miserable though strong consolation, that all mankind were involved in the same calamity, and that I imagined I was perishing with the world itself. At last this dreadful darkness was dissipated by degrees like a cloud of smoke: the real day returned, and even the sun appeared, though very faintly, and as when an eclipse is coming on. Every object that presented itself to our

* The Stoic and Epicurean philosophers held, that the world was to be destroyed by fire, and all things fall again into original chaos, not excepting even the national gods themselves from the destruction of this general conflagration.

eyes (which were extremely weakened) seemed changed, being covered over with white ashes* as with a deep snow. We returned to Misenum, where we refreshed ourselves as well as we could, and passed an anxious night between hope and fear; though indeed with a much larger share of the latter; for the earthquake still continued, while several enthusiastic people ran up and down, heightening their own and their friends' calamities by terrible predictions. However, my mother and I, notwithstanding the danger we had passed, and that which still threatened us, had no thoughts of leaving the place till we we should receive some account of my uncle.

And now you will read this narrative without any view of inserting it in your history, of which it is by no means worthy; and indeed you must impute it to your own request, if it shall appear scarce to deserve even the trouble of a letter. Farewel,

SECTION II.

Eruption of Vesuvius in 1766, *as described in a Letter from the Hon.* WILLIAM HAMILTON, *his Majesty's Envoy Extraordinary at Naples, to the Earl of* MORTON, *President of the Royal Society.*

NAPLES, *June* 10, 1766.

MY LORD,

As I have attended particularly to the various changes of Mount Vesuvius, from the 17th of November 1764, the day of my arrival at this capital, I flatter myself, that my observations will not be unacceptable to your lordship, especially as this volcano has lately made a very considerable eruption. I shall confine myself merely to the many extraordinary appearances that have come under my own inspection, and leave their explanation to the more learned in natural philosophy.

During the first twelvemonth of my being here, I did not perceive any remarkable alteration in the mountain; but I observed the smoke from the mouth of the volcano was much more considerable in bad weather than when it was fair; and I often heard (even at Naples, six miles from Vesuvius) in bad weather, the report of the

---

* Mr. Addison, in his account of mount Vesuvius, observes, that the air of the place is so very much impregnated with salt-petre, that one can scarce find a stone which has not the top white with it.

inward explosions of the mountain. When I have been at the top of Mount Vesuvius in fair weather, I have sometimes found so little smoke that I have been able to see far down the mouth of the volcano, the sides of which were incrusted with salts and minerals of various colours, white, green, deep and pale yellow. The smoke that issued from the mouth of the volcano in bad weather was white, very moist, and not near so offensive as the sulphureous steams from various cracks on the sides of the mountain.

Towards the month of September last, I perceived the smoke to be more considerable, and to continue even in fair weather; and in October I perceived sometimes a puff of black smoke shoot up a considerable height in the midst of the white, which symptom of an approaching eruption grew more frequent daily; and soon after, these puffs of smoke appeared in the night tinged like clouds with the setting sun.

About the beginning of November I went up the mountain; it was then covered with snow, and I perceived a little hillock of sulphur had been thrown up since my last visit there, within about forty yards of the mouth of the volcano; it was near six feet high, and a light blue flame issued constantly from its top. As I was examining this phenomenon, I heard a violent report, and saw a column of black smoke followed by a reddish flame, shoot up with violence from the mouth of the volcano, and presently fell a shower of stones, one of which falling near me, made me retire with some precipitation, and also rendered me more cautious of approaching too near, in my subsequent journies to Vesuvius.

From November to the 28th of March, the date of the beginning of this eruption, the smoke increased and was mixed with ashes, which fell, and did great damage to the vineyards in the neighbourhood of the mountain. A few days before the eruption I saw (what Pliny the younger mentions having seen, before that eruption of Vesuvius which proved fatal to his uncle) the black smoke take the form of a pine-tree. The smoke that appeared black in the day time for near two months, before the eruption had the appearance of flame in the night.

On Good Friday, the 28th of March, at seven o'clock at night, the lava began to boil over the mouth of the volcano, at first in one stream; and soon after, dividing itself into two, it took its course towards Portici. It was preceded by a violent explosion, which

caused a partial earthquake in the neighbourhood of the mountain, and a shower of red-hot stones and cinders were thrown up to a considerable height. Immediately upon sight of the lava, I left Naples with a party of my countrymen, whom I found as impatient as myself to satisfy their curiosity in examining so curious an operation of nature. I passed the whole night upon the mountain; and observed that, though the red-hot stones were thrown up in much greater number and to a more considerable height than before the appearance of the lava, yet the report was much less considerable than some days before the eruption. The lava ran near a mile in an hour's time, when the two branches joined in a hollow on the side of the mountain, without proceeding farther. I approached the mouth of the volcano, as near as I could with prudence; the lava had the appearance of a river of red-hot and liquid metal, such as we see in the glass-houses, on which were large floating cinders half lighted, and rolling one over another with great precipitation down the side of the mountain, forming a most beautiful and uncommon cascade; the colour of the fire was much paler and brighter on the first than the subsequent nights, when it became of a deep red, probably owing to its having been more impregnated with sulphur at first than afterwards. In the day time, unless you are quite close, the lava has no appearance of fire; but a thick white smoke marks its course.

The 29th the mountain was very quiet, and the lava did not continue. The 30th it began to flow again in the same direction, whilst the mouth of the volcano threw up every minute a girandole of red-hot stones, to an immense height. The 31st I passed the night upon the mountain; the lava was not so considerable as the first night, but the red-hot stones were perfectly transparent, some of which I dare say of a ton weight, mounted at least 200 feet perpendicular, and fell in, or near the mouth of a little mountain, that was now formed by the quantity of ashes and stones, within the great mouth of the volcano, and which made the approach much safer than it had been some days before, when the mouth was near half a mile in circumference, and the stones took every direction. Mr. Hervey, brother to the Earl of Bristol, was very much wounded in the arm some days before the eruption, having approached too near; and two English gentlemen with him were also hurt. It is impossible to describe the beautiful appearance of these girandoles

of red-hot stones, far surpassing the most astonishing artificial fire-work.

From the 31st of March to the 9th of April, the lava continued an the same side of the mountain in two, three, and sometimes four branches, without descending much lower than the first night. I remarked a kind of intermission in the fever of the mountain, which seemed to return with violence every other night. On the 10th of April at night the lava disappeared on the side of the mountain towards Naples, and broke out with much more violence on the side next the Torre dell' Annunciata.

I passed the whole day and the night of the 12th upon the mountain, and followed the course of the lava to its very source; it burst out of the side of the mountain, within about half a mile of the mouth of the volcano, like a torrent, attended with violent explosions, which threw up inflamed matter to a considerable height, the adjacent ground quivering like the timbers of a water-mill; the heat of the lava was so great as not to suffer me to approach nearer than within ten feet of the stream, and of such a consistency (though it appeared liquid as water) as almost to resist the impression of a a long stick, with which I made the experiment; and large stones thrown on it with all my force did not sink, but, making a slight impression, floated on the surface, and were carried out of sight in a short time; for, notwithstanding the consistency of the lava, it ran with amazing velocity; I am sure, the first mile with a rapidity equal to that of the river Severn, at the passage near Bristol. The stream at its source was about ten feet wide, but soon extended itself, and divided into three branches, so that these rivers of fire communicating their heat to the cinders of former lavas, between one branch and the other, had the appearance at night of a continued sheet of fire, four miles in length. and in some parts near two in breadth. Your lordship may imagine the glorious appearance of this uncommon scene, such as passes all description.

The lava, after having run pure for about 100 yards, began to collect cinders, stones, &c. and a scum was formed on its surface, which in the day time had the appearance of the river Thames, as I have seen it after a hard frost and great fall of snow, when beginning to thaw, carrying down vast masses of snow and ice. In two places the liquid lava totally disappeared, and ran in a subterraneous passage for some paces, then came out again pure, having left the

scum behind. In this manner it advanced to the cultivated parts of the mountain; and I saw it the same night of the 12th, unmercifully destroy a poor man's vineyard and surround his cottage, notwithstanding the opposition of many images of St. Januarius, that were placed upon the cottage, and tied to almost every vine. The lava, at the farthest extremity from its source, did not appear liquid, but like a heap of red-hot coals forming a wall, in some places ten or twelve feet high, which rolling from the top soon formed another wall, and so on, advancing slowly not more than about thirty feet in an hour.

The mouth of the volcano has not thrown up any large stones since the second eruption of lava, on the 10th of April, but has thrown up quantities of small ashes and pumice-stones, that have greatly damaged the neighbouring vineyards. I have been several times at the mountain since the 12th; but as the eruption was in its greatest vigour at that time, I have ventured to dwell on, and I fear tire your lordship with the observations of that day.

In my last visit to Mount Vesuvius the 3d of June, I still found that the lava continued, but the rivers were become rivulets, and had lost much of their rapidity. The quantity of matter thrown out by this eruption, is greater than that of the last in the year 1760, but the damage to the cultivated lands is not so considerable, owing to its having spread itself much more, and its source being at least three miles higher up. This eruption seems now to have exhausted itself; and I expect in a few days to see Vesuvius restored to its former tranquillity.

Mount Etna in Sicily broke out the 27th of April, and made a lava stream in two branches, at least six miles in length, and a mile in breadth, according to the description given me by Mr. Wilbraham, who was there, after having seen with me part of the eruption of mount Etna. Vesuvius resembles it in every respect, except that mount Etna, at the place from whence the lava flowed (which was twelve miles from the mouth of the volcano), threw up a fountain of liquid inflamed matter to a considerable height; which, I am told, mount Vesuvius has done in former eruptions.

I beg pardon for having taken up so much of your time, and yet I flatter myself, that my description, which I assure your lordship is not exaggerated, will have afforded you some amusement.

[*Phil. Trans.* 1767.]

SECTION III.

General Observations on the preceding Section, as described in a Letter from the same to MATTHEW MATY, *M. D. Secretary to the Royal Society.*

VILLA ANGELICA, *near* MOUNT VESUVIUS,
October 4, 1768.

SIR,

I HAVE but very lately received your last obliging letter of the 5th of July, with the volume of Philosophical Transactions.

I must beg of you to express my satisfaction at the notice the Royal Society have been pleased to take of my accounts of the two last eruptions * of Mount Vesuvius. Since I have been at my villa here, I have enquired of the inhabitants of the mountain after what they had seen during the last eruption. In my letter to Lord Morton, I mentioned nothing but what came immediately under my own observation: but as all the peasants here agree in their account of the terrible thunder and lightning, which lasted almost the whole time of the eruption, upon the mountain only; I think it a circumstance worth attending to. Besides the lightning, which perfectly resembled the common forked lightning, there were many meteors, like what are vulgarly called falling stars. A peasant, in my neighbourhood, lost eight hogs by the ashes falling into the trough with their foo d:they grew giddy, and died in a few hours. The last day of the eruption, the ashes, which fell abundantly upon the mountain, were as white almost as snow; and the old people here assure me, that is a sure symptom of the eruption being at an end. These circumstances being well attested, I thought worth relating.

It would require many years close application, to give a proper and truly philosophical account of the volcanoes in the neighbourhood of Naples: but I am sure such a history might be given, supported by demonstration, as would destroy every system hitherto given upon this subject. We have here an opportunity of seeing volcanoes in all their states. I have been this summer in the island of Ischia; it is about eighteen miles round, and its whole basis is lava. The great mountain in it, near as high as Vesuvius, formerly called Epomeus, and now San Nicolo, I am convinced was thrown up by degrees; and I have no doubt in my own mind, but that the

* Sir William in this passage refers to a second letter upon the same subject, which we have not thought it necessary to copy.—*Editor.*

island itself rose out of the sea in the same manner as some of the Azores. I am of the same opinion with respect to Mount Vesuvius, and all the high grounds near Naples; as having not yet seen, in any one place, what can be called virgin earth. I had the pleasure of seeing a well sunk, a few days ago, near my villa, which is, as you know, at the foot of Vesuvius, and close by the sea side. At twenty-five feet below the level of the sea they came to a stratum of lava, and God knows how much deeper they might have still found other lavas. The soil all round the mountain, which is so fertile, consists of stratas of lavas, ashes, pumice, and now and then a thin stratum of good earth, which good earth is produced by the surface mouldering, and the rotting of the roots of plants, vines, &c. This is plainly to be seen at Pompeii, where they are now digging into the ruins of that ancient city; the houses are covered, about ten or fifteen feet, with pumice and fragments of lava, some of which weigh three pounds (which last circumstance I mention to shew, that, in a great eruption, Vesuvius has thrown stones of this weight six miles, which is its distance from Pompeii, in a direct line); upon this stratum of pumice, or rapilli, as they call them here, is a stratum of excellent mould, about two feet thick, on which grow large trees, and excellent grapes. We have then the Solfaterra, which was certainly a volcano, and has ceased from operating, for want of metallic particles and over-abounding with sulphur. You may trace its lavas into the sea. We have the Lago d'Averno, and the Lago dAgnano, both of which were formerly volcanoes; and Astroni, which still retains its form more than any of these. Its crater is walled round, and his Sicilian majesty takes the diversion of boar hunting in this volcano; and neither his majesty, or any one of his court, ever dreamed of its former state. We have then that curious mountain, called Montagno Nuovo, near Puzzole, which rose, in one night, out of the Lucrine Lake; it is about 150 feet high and three miles round. I do not think it more extraordinary, that Mount Vesuvius, in many ages, should rise above 2000 feet; when this mountain, as is well attested, rose in one night, no longer ago than the year 1538. I have a project, next spring, of passing some days at Puzzole, and of dissecting this mountain, taking its measures, and making drawings of its stratas; for, I perçeive, it is composed of stratas, like Mount Vesuvius, but without lavas. As this mountain is so undoubtedly formed entirely from a plane, I should think my project may give light into the formation of many other mountains, that are at present

thought to have been original, and are certainly not so, if their strata correspond with those of the Montagno Nuovo. I should be glad to know whether you think this project of mine will be useful; and, if you do, the result of my observations may be the subject of another letter.

I cannot have a greater pleasure than to employ my leisure hours in what may be of sóme little use to mankind; and my lot has carried me into a country, which affords an ample field for observation. Upon the whole, if I was to establish a system, it would be, that mountains are produced by volcanoes, and not volcanoes by mountains.

I fear I have tired you: but the subject of volcanoes is so favourite a one with me, that it has led me on I know not how: I shall only add, that Vesuvius is quiet at present, though very hot at top, where there is a deposition of boiling sulphur. The lava that run in the Fossa Grande during the last eruption, and is at least 200 feet thick, is not yet cool; a stick, put into its crevices, takes fire immediately. On the sides of the crevices are fine crystalline salts: as they are the pure salts, which exhale from the lava that has no communication with the interior of the mountain, they may perhaps indicate the composition of the lava.

[*Phil. Trans.* 1769.]

SECTION IV.

Eruption of Vesuvius in 1799, *as described in a Letter from* SIR WILLIAM HAMILTON, K.B. F.R.S. *to* JOSEPH BANKS, ESQ. F.R.S.

NAPLES, *October* 1, 1779.

SIR,

THE late eruption of Mount Vesuvius was of so singular a nature, so very violent and alarming, that it necessarily attracted the attention of every one, not only in its immediate neighbourhood, but for many miles around; and, consequently, several slight descriptions of it have been already handed about, and some (as I am informed) more accurate and circumstantial are preparing for the press*.

* The inhabitants of this great city in general give so little attention to Mount Vesuvius, though in full view of the greatest part of it, that I am well convinced many of its eruptions pass totally unnoticed by at least two-thirds of them.

That on which the Abbot Bottis is actually employed, by command of his Sicilian Majesty, will undoubtedly be executed with the same accuracy, truth, and precision, as have rendered that author's former publications upon the subject of Mount Vesuvius so universally and deservedly esteemed.

Such a publication, executed with magnificence in the royal printing office, may, perhaps, render every other account of the late eruption superfluous: nevertheless, I should think myself in some degree guilty of a neglect towards the Royal Society, who have done so much honour to my former communications, if I did not, through the respectable channel of its worthy president, and my good friend, simply relate to them such remarkable circumstances as attended the late tremendous explosions of Mount Vesuvius, and as either came immediately under my own inspection, or have been related to me by such good authority as cannot be called in question.

Since the great eruption of 1767, of which I had the honour of giving a particular account to the Royal Society, Vesuvius has never been free from smoke, nor ever many months without throwing up red-hot scoriæ, which, increasing to a certain degree, were usually followed by a current of liquid lava; and, except in the eruption of 1777, those lavas broke out nearly from the same spot, and ran much in the same direction, as that of the famous eruption of 1767.

No less than nine such eruptions are recorded here since the great one above-mentioned, and some of them were considerable. I never failed visiting those lavas whilst they were in full force, and as constantly examined them and the crater of the volcano after the ceasing of each eruption *.

It would be but a repetition of what has been described in my former letters on this subject, were I to relate my remarks on those different expeditions. The lavas, when they either boiled over the crater, or broke out from the conical parts of the volcano, con-

* The last visit to the crater of Vesuvius, which was in the month of May, 1799, was my fifty-eighth, and to be sure I have been four times as often on parts of the mountain, without climbing to its summit, and after all am not ashamed to own, that I comprehend very little of the wonders I have seen in this great laboratory of nature; yet there have been naturalists of such a wonderful penetrating genius, as to have thought themselves sufficiently qualified to account for every hidden phenomenon of Vesuvius, after having, literally speaking, given the volcano *un coup d'œil.*

stantly formed channels as regular as if they had been cut by art down the steep part of the mountain, and, whilst in a state of perfect fusion, continued their course in those channels, which were sometimes full to the brim, and at other times more or less so, according to the quantity of matter in motion.

These channels, upon examination after an eruption, I have found to be in general from two to five or six feet wide, and seven or eight feet deep. They were often hid from the sight by a quantity of *scoriæ* that had formed a crust over them, and the lava having been conveyed in a covered way for some yards, came out fresh again into an open channel. After an eruption I have walked in some of those subterraneous or covered galleries which were exceedingly curious, the sides, top, and bottom, being worn perfectly smooth and even in most parts by the violence of the currents of the red-hot lavas, which they had conveyed for many weeks successively; in others, the lava had incrusted the sides of those channels with some very extraordinary *scoriæ*: beautifully ramified with white salts,* in the form of dropping stalactites, were also attached to many parts of the ceiling of those galleries. It is imagined here, that the salts of Vesuvius are chiefly ammoniac, though often tinged with green, deep, or pale yellow, by the vapour of various minerals.

In the month of May last, there was a considerable eruption of Mount Vesuvius, when I passed a night on the mountain in the company of one of my countrymen, as eager as myself in the pursuit of this branch of natural history †.

We saw the operation of the lava, in the channels as abovementioned, in the greatest perfection; but it was, indeed, owing to our perseverance, and some degree of resolution. After the lava had quitted its regular channels, it spread itself in the valley, and, being loaded with *scoriæ*, ran gently on, like a river that had been frozen, and had masses of ice floating on it: the wind changing when we were close to this gentle stream of lava, which might be about fifty or sixty feet in breadth, incommoded us so much with its heat and smoke, that we must have returned without having satisfied

---

* I sent a large specimen of this curious volcanic production to the British Museum last year.

† Mr. Bowdler, of Bath.

our curiosity, had not our guide* proposed the expedient of walking across it, which, to our astonishment, he instantly put in execution, and with so little difficulty, that we followed him without hesitation, having felt no other inconveniency than what proceeded from the violence of the heat on our legs and feet; the crust of the lava was so tough, besides being loaded with cinders and *scoriæ*, that our weight made not the least impression on it, and its motion was so slow, that we were not in any danger of losing our balance and falling on it: however, this experiment should not be tried except in cases of real necessity; and I mention it with no other view than to point out a possibility of escaping, should any one hereafter, upon such an expedition as ours, have the misfortune to be inclosed between two currents of lava.

Having thus got rid of the troublesome heat and smoke, we coasted the river of lava and its channels up to its very source, within a quarter of a mile of the crater. The liquid and red-hot matter bubbled up violently, with a hissing and crackling noise, like that which attends the playing off of an artificial firework; and, by the continual splashing up of the vitrified matter, a kind of arch or dome was formed over the crevice from which the lava issued. It was cracked in many parts, and appeared red-hot within, like an heated oven: this hollowed hillock might be about fifteen feet high, and the lava that ran from under it was received into a regular channel, raised upon a sort of wall of *scoriæ* and cinders, almost perpendicularly, of about the height of eight or ten feet, resembling much an ancient aqueduct.

We then went up to the crater of the volcano, in which we found, as usual, a little mountain throwing *scoriæ* and red-hot matter with loud explosions; but the smoke and smell of sulphur was so intolerable, that we were under the necessity of quitting that curious spot with the utmost precipitation.

In another of my excursions to Mount Vesuvius last year, I picked up some fragments of large and regular crystals of close-grained lava or basalt, the diameter of which, when the prisms were complete, may have been eight or nine inches. As Vesuvius does not exhibit any lavas regularly crystallized, and forming what are vulgarly called Giants Causeways (except a lava that ran into the sea

* Bartolomeo, the Cyclops of Vesuvius, who has attended me on all my expeditions to the mountain, and who is an excellent guide.

near Torre del Greco in 1631, and which in a small degree has such an appearance), this discovery gave me the greatest pleasure *.

After this slight sketch of the most remarkable events on Vesuvius since the year 1767, which I flatter myself will not be unacceptable, as it may serve to connect what I am going to relate with what has already been communicated to the Society in my former letters on the same subject, I come to the account of the late eruption, which affords indeed ample matter for curious speculation.

As many poetical descriptions of this eruption will not be wanting, I shall confine mine to simple matter of fact in plain prose, and endeavour to convey to you, Sir, as clearly and as distinctly as I am able, what I saw myself, and the impression it made upon me at the time, without aiming in the least at a flowery style.

The usual symptoms of an approaching eruption, such as rumbling noises and explosions within the bowels of the volcano, a quantity of smoke issuing with force from its crater, accompanied at times with an emission of red-hot *scoriæ* and ashes, were manifest, more or less, during the whole month of July; and towards the end of the month, those symptoms were increased to such a degree as to exhibit in the night-time the most beautiful fire-works that can be imagined.

These kinds of throws of red-hot *scoriæ* and other volcanic matter, which at night are so bright and luminous, appear in broad day-light like so many black spots in the midst of the white smoke; and it is this circumstance that occasions thé vulgar and false supposition, that volcanoes burn much more violently at night than in the day-time.

On Thursday, the 5th of August last, about two o'clock in the afternoon, I perceived from my villa at Pausilipo in the bay of Naples, from whence I have a full view of Vesuvius (which is just

* As the fragments of basalt columns, which I found on the cone of Vesuvius, had been evidently thrown out of its crater, may not lava be more subject to crystallize within the bowels of a volcano than after its emission, and having been exposed to the open air? And may not many of the Giants' Causeways, already discovered, be the *nuclei* of volcanic mountains, whose lighter and less solid parts may have been worn away by the hand of time? Mr. Faujais de St. Fond, in his curious book lately published, and intitled, "Recherches sur les Volcains eteints du Vivarais et du Velay," gives (p. 286) an example of basalt columns, that are placed deep within the crater of an extinguished volcano.

opposite, and at the distance of about six miles in a direct line from it) that the volcano was in a most violent agitation: a white and sulphureous smoke issued continually and impetuously from its crater, one puff impelling another, and by an accumulation of those, clouds of smoke resembling bales of the whitest cotton. Such a mass of them was soon piled over the top of the volcano as exceeded the height and size of the mountain itself at least four times. In the midst of this very white smoke, an immense quantity of stones, *scoriæ*, and ashes, were shot up to a wonderful height, certainly not less than two thousand feet. I could also perceive, by the help of one of Ramsden's most excellent refracting telescopes, at times, a quantity of liquid lava, seemingly very weighty, just heaved up high enough to clear the rim of the crater, and then take its course impetuously down the steep side of Vesuvius, opposite to Somma. Soon after a lava broke out on the same side from about the middle of the conical part of the volcano, and, having run with violence some hours, ceased suddenly, just before it had arrived at the cultivated parts of the mountain above Portici, near four miles from the spot where it issued.

During this day's eruption, as I have been credibly informed since, the heat was intolerable at the towns of Somma and Ottaiano; and was likewise sensibly felt at Palma and Lauro, which are much farther from Vesuvius than the former. Minute ashes, of a reddish hue, fell so thick at Somma and Ottaiano, that they darkened the air in such a manner that objects could not be distinguished at the distance of ten feet. Long filaments of a vitrified matter like spun-glass were mixed and fell with these ashes*; and the sulphureous smoke was so violent, that several birds in cages were suffocated, the leaves of the trees in the neighbourhood of Somma and

* During an eruption of the volcano in the Isle of Bourbon in 1766, some miles of country, at the distance of six leagues from that volcano, were covered with a flexible, capillary, yellow glass, some pieces of which were two or three feet long, with small vitreous globules at a little distance one from the other. Count Buffon shewed me some of this capillary and flexible glass, which is preserved in the Royal Museum at Paris, and which perfectly resembles the filaments of vitrified matter which fell at Ottaiano and in other parts on the borders of Vesuvius during this eruption. Sorrentino, in his Istoria del Vesuvio, published at Naples in 1734, likewise mentions vitrified matter, like herbs and straw, being found on the ground in the neighbourhood of Vesuvius during an eruption of that mountain in the year 1724.

Ottaiano were covered with white salts very corrosive. About two o'clock in the afternoon, an extraordinary globe of smoke, of a very great diameter, was distinctly perceived, by many of the inhabitants of Portici, to issue from the crater of Vesuvius, and proceed hastily towards the mountain of Somma, against which it struck and dispersed itself, having left a train of white smoke, marking the course it had taken: this train I perceived plainly from my villa, as it lasted some minutes; but I did not see the globe itself.

A poor labourer, who was making faggots on the mountain of Somma, lost his life at this time, and his body not having been found, it is supposed that, suffocated by the smoke, he must have fallen into the valley from the craggy rocks on which he was at work, and been covered by the current of lava that took its course through that valley soon after. An ass, that was waiting for its master in the valley, left it very judiciously as soon as the mountain became violent, and, arriving safe home, gave the first alarm to this poor man's family.

It was generally remarked, that the explosions of the volcano were attended with more noise during this day's eruption than in any of the succeeding ones, when, most probably, the mouth of Vesuvius was widened, and the volcanic matter had a freer passage. It is certain, however, that the great eruption of 1767 (which in every other respect was mild, when compared to the late violent eruption) occasioned much greater concussions in the air by its louder explosions.

Friday, August the 6th, the fermentation in the mountain was less violent; but, about noon, there was a loud report, at which time it was supposed, that a portion of the little mountain within the crater had fallen in. At night the throws from the crater increased, and proceeded evidently from two separate mouths, which emitting red-hot *scoriæ*, and in different directions, formed a most beautiful and almost continued fire-work.

On Saturday, August the 7th, the volcano remained much in the same state; but, about twelve o'clock at night, its fermentation increased greatly. The second fever-fit of the mountain may be said to have manifested itself at this time. I was watching its motions from the mole of Naples, which has a full view of the volcano, and had been witness to several glorious picturesque effects produced by the reflection of the deep red fire, which issued from the crater

of Vesuvius, and mounted up in the midst of the huge clouds, when a summer storm, called here a *tropea*, came on suddenly, and blended its heavy watery clouds with the sulphureous and mineral ones, which were already like so many other mountains piled over the summit of the volcano; at this moment a fountain of fire was shot up to an incredible height, casting so bright a light, that the smallest objects could be clearly distinguished at any place within six miles or more of Vesuvius.

The black stormy clouds passing swiftly over, and at times covering the whole or a part of, the bright column of fire, at other times clearing away, and giving a full view of it, with the various tints produced by its reverberated light on the white clouds above, in contrast with the pale flashes of forked lightning that attended the *tropea*, formed such a scene as no power of art can ever express.

That which followed the next evening was surely much more formidable and alarming; but this was more beautiful and sublime than even the most lively imagination can paint to itself. This great explosion did not last above eight or ten minutes, after which Vesuvius was totally eclipsed by the dark clouds, and there fell a heavy shower of rain.

Some *scoriæ* and small stones fell at Ottaiano during this eruption, and some of a very great size in the valley between Vesuvius and the Hermitage. All the inhabitants of the towns at the foot of the volcano were in the greatest alarm, and preparing to abandon their houses, had the eruption continued longer.

One of his Sicilian Majesty's game-keepers, who was out in the fields near Ottaiano whilst this combined storm was at its height, was greatly surprised to find the drops of rain scald his face and hands, which phenomenon was probably occasioned by the clouds having acquired a great degree of heat in passing through the above mentioned column of fire. The King of Naples did me the honour of informing me of this curious circumstance.

Sunday, August the 8th, Vesuvius was quiet till towards six o'clock in the evening, when a great smoke began to gather again over its crater, and about an hour after, a rumbling subterraneous noise was heard in the neighbourhood of the volcano; the usual throws of red-hot stones and *scoriæ* began, and increased every instant. I was at this time at Pausilipo, in the company of several of my country-

men, observing with good telescopes the curious phænomena in the crater of Vesuvius, which, with such help, we could distinguish as well as if we had been actually seated on the summit of the volcano. The crater seemed much enlarged by the violence of last night's explosions, and the little mountain no longer existed. At about nine o'clock there was a loud report, which shook the houses at Portici and its neighbourhood to such a degree as to alarm their inhabitants, and drive them out into the streets; and, as I have since seen, many windows were broken, and walls cracked, by the concussion of the air from that explosion, though faintly heard at Naples.

In an instant a fountain of liquid transparent fire began to rise, and, gradually increasing, arrived at so amazing a height as to strike every one who beheld it with the most awful astonishment. I shall scarcely be credited when I assure you, Sir, that, to the best of my judgment, the height of this stupendous column of fire could not be less than three times that of Vesuvius itself, which, as you know, rises perpendicularly near 3700 feet above the level of the sea*.

Puffs of smoke, as black as can possibly be imagined, succeeded one another hastily, and accompanied the red-hot, transparent, and liquid lava, interrupting its splendid brightness here and there by patches of the darkest hue. Within these puffs of smoke, at the very moment of their emission from the crater, I could perceive a bright, but pale, electrical fire, briskly playing about in zig-zag lines †.

The wind was S.W.; and though gentle was sufficient to carry these detached clouds or puffs of smoke out of the column of fire, and a collection of them, by degrees, formed a black and extensive curtain (if I may be allowed the expression) behind it; in other parts of the sky it was perfectly clear, and the stars were bright.

---

* Se tu se' or lettore, a creder lento
Ció, ch'e Io dirò, non sarà maraviglia;
Che Io, che l' vidi; appena il mi consento.
Dante Inf. Cant. xxv. verso 46.

† I mention this circumstance to prove, that the electrical matter, so manifest during this eruption, actually proceeded from the bowels of the volcano, and was not attracted from a great height in the air, and conducted into its crater by the vast column of smoke.

The fiery fountain, of so gigantic a size, upon the dark ground above mentioned, made the most glorious contrast imaginable, and the blaze of it reflected strongly on the surface of the sea, which was at that time perfectly smooth, added greatly to this sublime view.

The liquid lava, mixed with stones and *scoriæ*, after having mounted, I verily believe, at the least ten thousand feet, was partly directed by the wind towards Ottaiano, and partly falling almost perpendicularly, still red-hot and liquid, on Vesuvius, covered its whole cone, part of that of the mountain of Somma, and the valley between them. The falling matter being nearly as vivid and inflamed as that which was continually issuing fresh from the crater, formed with it one complete body of fire, which could not be less than two miles and a half in breadth, and of the extraordinary height above mentioned, casting a heat to the distance of at least six miles around it.

The brush-wood on the mountain of Somma was soon in a blaze, which flame, being of a different tint from the deep red of the matter thrown out of the volcano, and from the silvery blue of the electrical fire, still added to the contrast of this most extraordinary scene.

The black cloud increasing greatly once bent towards Naples, and seemed to threaten this fair city with speedy destruction; for it was charged with electrical matter, which kept constantly darting about it in strong and bright zig-zags, just like those described by Pliny the younger in his letter to Tacitus, and which accompanied the great eruption of Vesuvius that proved fatal to his uncle *. This volcanic lightning, however, as I particularly remarked, very rarely quitted the cloud, but usually returned to the great column of fire towards the crater of the volcano from whence it originally came†. Once

* "Ab altero latere, nubes atra, et horrenda, ignei spiritus tortis vibratisque discursibus rupta, in longas flammarum figuras dehiscebat; fulgoribus illæ, et similes et majores." Plin. Epist.

† Sorrentino mentions the like observation, which he made during an eruption of Vesuvius in 1707, when the same kind of black cloud bent over Naples; these are his words. "Alle ore 19, tutti i cittadini nelle oscure tenebre si trovarono in mezzo delle Saëtte, delle quali, alcune vedeansi uscir dalla fornace del Vesuvio, e scorrere sino al capo di Pausilipo, d'onde non passando più inanzi fuor la nuvola delle ceneri, o divertirsi altronde, indietro per l'istessa linea tornarono a scopiar su la fornace, onde uscirono: qual moto retrogrado mai ha potuto intendere."

or twice, indeed, I saw this lightning (or *ferilli*, as it is called here) fall on the top of Somma, and set fire to some dry grass and bushes*.

Fortunately for us the wind increasing from the S. W. quarter, carried back the threatening cloud just as it had reached the city, and began to occasion great alarm. All public diversions ceased in an instant, and the theatres being shut, the doors of the churches were thrown open. Numerous processions were formed in the streets, and women and children, with dishevelled heads, filled the air with their cries, insisting loudly upon the relics of St. Januarius being immediately opposed to the fury of the mountain: in short, the populace of this great city began to display its usual extravagant mixture of riot and bigotry, and if some speedy and well-timed precautions had not been taken, Naples would, perhaps, have been in more danger of suffering from the irregularities of its lower class of inhabitants, than from the angry volcano.

But to return to my subject: After the column of fire had continued in full force near half an hour, the eruption ceased all at once, and Vesuvius remained sullen and silent. After the dazzling light of the fiery fountain †, all seemed dark and dismal, except the cone of Vesuvius, which was covered with glowing cinders and *scoriæ*, from under which, at times, here and there, small streams of liquid lava escaped, and rolled down the steep sides of the volcano. This scene put me in mind of Martial's description of Etna:

Cuncta jacent flammis et tristi mersa favillâ.

In the parts of Naples nearest Vesuvius, whilst the eruption lasted, a mixed smell, like that of sulphur, with the vapours of an iron

---

* Some time after the eruption had ceased, the air continued greatly impregnated with electrical matter. The Duke of Cotrosiano, a Neapolitan nobleman (who, from his superior knowledge in experimental philosophy and mechanics, does honour to his country) told me, that having, about half an hour after the great eruption had ceased, held a Leyden bottle, armed with a pointed wire, out of his window at Naples, it soon became considerably charged. Whilst the eruption was in force, its appearance was too alarming to allow one to think of such experiments.

† The light diffused by this huge column of fire was so strong, that the most minute objects could be discerned clearly within the compass of ten miles or more round the mountain. Mr. Morris an English gentleman, told me, that at Sorrento, which is twelve miles from Vesuvius, he read the title page of a book by that volcanic light.

foundery, was sensible; but nearer to the mountain that smell was very offensive, as I have often found it in my visits to Vesuvius during an eruption.

Thus, Sir, have I endeavoured to convey to you at least a faint idea of a scene so glorious and sublime as, perhaps, may have never before been viewed by human eyes, at least in such perfection.

I am sensible, from the traces of them I have observed in the volcanic strata, which compose the greatest part of this country, that there have been many more considerable eruptions than the one just described; yet, most probably, those very violent eruptions must either have been attended with earthquakes, and other such alarming circumstances, as to make the beholders less attentive to the beauty of the scenes such phænomena offered than to their own safety; or clouds of smoke and ashes, as is usually the case in all great eruptions, must have so far obscured the volcano, as to exhibit only a confused mass of fire and smoke.

Whilst we had been enjoying the extraordinary sight of this gigantic fountain of liquid fire in perfect safety, the unfortunate inhabitants of the other side of the mountain of Somma, particularly at Ottaiano and Cacciabella, were involved in that dark and sooty cloud which formed so proper a back ground to our bright picture, and were pelted with stones and *scoriæ* of lava; but I shall presently give you a particular description of their truly distressful situations, just as I had it from many of the poor sufferers themselves, when I visited that part of the country a few days after this eruption.

Monday, August the 9th, about nine o'clock in the morning, the fourth fever-fit of the mountain began to manifest itself by the usual symptoms, such as a subterraneous boiling noise, violent explosions of inflamed matter from the crater of the volcano, accompanied with smoke and ashes, which symptoms increased every instant. The smoke was of two sorts; the one as white as snow, and the other as black as jet.

The white, as described in the former part of this journal, rolled gently mass over mass, resembling bales of the softest cotton; and the black composed of *scoriæ* and minute ashes shot up with force in the midst of the white smoke, which, from the minerals, was also sometimes tinged with yellow, blue, and green. Presently such a tremendous mass of these accumulated clouds stood over Vesuvius

as seemed to threaten Naples again, and actually made the mountain itself appear a mole hill.

This day's eruption was similar to that of Thursday last, but many degrees more violent. Some stones, thrown near as high as those of last night, fell on the mountain of Somma, and set fire to the brush-wood with which it is covered; but there being little wind, and that westerly, the volcanic matter rose and fell in a more perpendicular direction, and Ottaiano did not suffer by this day's eruption; but most of the inhabitants of the towns, on the borders of Vesuvius, fled to Naples, alarmed by the tremendous clouds and the loud explosions.

We remarked, that several very large stones, after having mounted to an immense height, formed a parabola, leaving behind them a trace of white smoke that marked their course: some burst in the air exactly like bombs, and others fell into the valley between Somma and Vesuvius without bursting; others again burst into a thousand pieces soon after their emission from the crater: they might very properly be called volcanic bombs.

In the smoke issuing from the crater of Vesuvius we often remarked a sudden brisk and quivering motion, which seemed to communicate itself instantaneously from one cloud to another, and sometimes affected those that were very high in the great mass above the volcano. Though I could not discern any electrical fire, yet I make no doubt, but that the effect above mentioned was occasioned by it, and would have been visible in the night-time.

Upon the whole, this day's eruption was very alarming; until the lava broke out about two o'clock, and ran three miles between the two mountains, we were in continual apprehension of some fatal event. It continued to run about three hours, during which time every other symptom of the mountain fever gradually abated, and at seven o'clock at night all was calm.

It was universally remarked, that the air this night, for many hours after the eruption, was filled with meteors, such as are vulgarly called falling stars; they shot generally in an horizontal direction, leaving a luminous trace behind them, but which quickly disappeared. The night was remarkably fine, star-light, and without a cloud. This kind of electrical fire seemed to be harmless, and never to reach the ground; whereas that with which the black volcanic cloud of last night was pregnant appeared mischievous, like the

lightning that attends a severe thunder storm, as we should undoubtedly have experienced, had the eruption continued longer, and the cloud spread over Naples. The same kind of lightning proved fatal to several people, and did great damage within the space of many miles round Vesuvius during its great eruption of 1631, as is mentioned in one of my former letters on this subject.

During this day's eruption the relics of St. Januarius were carried in procession, and exposed to the furious mountain from the bridge of the Maddalena, amidst a prodigious concourse of people, who are at this moment well convinced, that to this ceremony alone Naples may attribute its happy escape.

It was from their Sicilian Majesties palace at Pausilipo that I made my observations on this day's eruption, and in the presence of their Majesties, who had been pleased to send for me in the morning, as soon as the volcano became turbulent.

Tuesday, August the 10th, Vesuvius was quiet.

Wednesday, August the 11th, about six o'clock in the morning, the fifth and last fever-fit of the mountain came on, and gradually increased. About twelve o'clock it was at its height*, and very violent indeed, the explosions being louder than those that attended the former eruptions, we could not judge of the height of the vollies of stones and *scoriæ*, as some rainy clouds were blended with the volcanic ones, and hid the upper part of the cone and crater of Vesuvius from our view.

The same mountains of white cotton-like clouds, piled one over another, rose to such an extraordinary height, and formed such a colossal mass over Vesuvius, as cannot possibly be described, or scarcely imagined. It may have been from a scene of this kind, that the ancient poets took their ideas of the giants waging war with Jupiter.

About five o'clock in the evening the eruption ceased; some rain having fallen this day, which having been greatly impregnated with the corrosive salts of the volcano, did much damage to the vines in its neighbourhood.

Thursday and Friday, the 12th and 13th of August, Vesuvius

* It has been remarked by the oldest people in the neighbourhood of Vesuvius, that in its eruptions the volcano is subject to a crisis at noon and midnight; and, indeed, from my own observation, I believe that remark to be well-founded.

continued to smoke considerably, and at times slight explosions were heard, like cannon at a great distance; but there have been no more throws from its crater, nor any streams of lava from its flanks, since Wednesday last.

On Saturday, August the 15th, I went, accompanied by Count Lamberg, the Imperial Minister at this Court, to visit Ottaiano and Caccia-bella, the district which had been most severely treated by the heavy and destructive shower of volcanic matter from the crater of Vesuvius last Sunday night.

Soon after having passed the town of Somma, we began to perceive, that the heat of the fiery shower, which had fallen in its neighbourhood, had affected the leaves of the trees and vines, which we found still more parched and shrivelled in proportion as we approached the town of Ottaiano, which may be about three miles from Somma. At about the distance of a mile from Somma, we began to perceive fresh cinders or *scoriæ* of lava, thinly scatter ed on the road and in the fields. Every step we advanced we fonnd them of a larger dimension, and in greater abundance. At the distance of a mile and a half from Ottaiano, the soil was totally covered by them, and the leaves and fruit were either intirely stripped from the trees, or remained thinly on them, shrivelled and dried up by the intense heat of the volcanic shower.

After having passed through the most fertile country, abounding with trees loaded with fruits of every kind, and the most luxuriant vegetation, through gay villages crouded with chearful inhabitants, to come at once to such a scene of desolation and misery, affording to our view nothing but heaps of black cinders and ashes, blasted trees, ruined houses, with a few of their scattered inhabitants just returned with ghastly, dismayed countenances, to survey the havock done to their tenements and habitations, and from which they themselves had with much difficulty escaped alive on Sunday last, was such a melancholy scene as can neither be described or forgotten.

We found the roof of his Sicilian Majesty's sporting-seat at Caccia-bella much damaged by the fall of large stones and heavy *scoriæ*, some of which, after having been broken by their fall through the roof, still weighed upwards of thirty pounds. This place, in a direct line, cannot be less than four miles from the crater of Vesuvius.

The most authentic accounts have been received of the fall of small volcanic stones and cinders (some of which weighed two

ounces) at Benevento, Foggia, and Monte Mileto, upwards of thirty miles from Vesuvius *; but what is most extraordinary (as there was but little wind during the eruption of the 8th of August) minute ashes fell thick that very night upon the town of Manfredonia, which is at the distance of an hundred miles from Vesuvius †.

These facts seem to confirm the extreme supposed height of the column of fire that issued from the crater of Vesuvius last Sunday night, and are greatly in support of what we find recorded in the history of Vesuvius with respect to the fall of its ashes at an amazing distance, and in a short space of time, during its violent eruption.

We proceeded from Caccia-bella to Ottaiano, which is a mile nearer to Vesuvius, and is reckoned to contain twelve thousand inhabitants. Nothing could be more dismal than the sight of this town, unroofed, half buried under black *scoriæ* and ashes, all the windows towards the mountain broken, and some of the houses themselves burnt, the streets choaked up with these ashes (in some that were narrow, the *stratum* was not less than four feet thick), and a few of the inhabitants just returned were employed in clearing them away, and piling up the ashes in hillocks to get at their ruined houses. Others were assembled in little groups, inquiring after their friends and neighbours, relating each other's woes, crossing themselves, and lifting up their eyes to Heaven when they mentioned their miraculous escapes. Some monks, who were in their convent during the whole of the horrid shower, gave us the following particulars, which they related with solemnity and precision.

The mountain of Somma, at the foot of which Ottaiano is situated,

---

* The prince of Monte Mileto told me, that his son, the Duke of Popoli, who was at Monte Mileto the 8th of August, had been alarmed by the shower of cinders that fell there, some of which he had sent to Naples, weighing two ounces; and that stones of an ounce had fallen upon an estate of his ten miles farther off. Monte Mileto is about thirty miles from the volcano.

† The Abbé Galliani, well known in the literary world, told me, that his sister, a nun in a convent at Manfredonia, had wrote to enquire after him, imagining that Naples must have been destroyed, when they, at so great a distance, had been so much alarmed by a shower of minute ashes, which fell on that city at eleven o'clock at night, the 8th of August, as to open all the churches, and go to prayers. As the great eruption happened at nine o'clock at night, the ashes must have travelled an hundred miles within the short space of two hours.

hides Vesuvius from its sight, so that till the eruption became considerable it was not visible to them. On Sunday night, when the noise increased, and the fire began to appear above the mountain of Somma, many of the inhabitants of this town flew to the churches, and others were preparing to quit the town, when a sudden violent report was heard; soon after which they found themselves involved in a thick cloud of smoke and minute ashes: a horrid clashing noise was heard in the air, and presently fell a deluge of stones and large *scoriæ*, some of which *scoriæ* were of the diameter of seven or eight feet, and must have weighed more than an hundred pounds before they were broken by their fall, as some of the fragments of them, which I picked up in the streets, still weighed upwards of sixty pounds. When these large vitrified masses either struck against one another in the air, or fell on the ground, they broke in many pieces, and covered a large space around them with vivid sparks of fire, which communicated their heat to every thing that was combustible*. In an instant the town, and country about it, was on fire in many parts; for in the vineyards there were several straw huts, which had been erected for the watchmen of the grapes, all of which were burnt. A great magazine of wood in the heart of the town was all in a blaze, and, had there been much wind, the flames must have spread universally, and all the inhabitants would have infallibly been burnt in their houses, for it was impossible for them to stir out. Some who attempted it with pillows, tables, chairs, the tops of wine casks, &c. on their heads, were either knocked down, or soon driven back to their close quarters under arches, and in the cellars of their houses. Many were wounded, but only two persons have died of the wounds they received from this dreadful volcanic shower. To add to the horror of the scene, incessant volcanic lightning was whisking about the black cloud that surrounded them, and the sulphureous smell and heat would scarcely allow them to draw their breath.

In this miserable and alarming situation they remained about twenty-five minutes, when the volcanic storm ceased all at once,

---

* The masses were formed of the liquid lava, the exterior parts of which had become black and porous by cooling in the long traverse they had made through the air, whilst the interior parts, less exposed, retained an extreme heat, and were perfectly red.

and the frightened inhabitants of Ottaiano, apprehending a fresh attack from the turbulent mountain, hastily quitted the country, after having deposited the sick and bed-ridden, at their own desire, in the churches.

Had the eruption lasted an hour longer, Ottaiano must have remained exactly in the state of Pompeia, which was buried under the ashes of Vesuvius just 1700 years ago, with most of its inhabitants, whose bones are to this day frequently found under arches and in the cellars of the houses of that ancient city. which

We were told of many miracles that had been wrought by the images of saints at this place during the late disaster; but as they are quite foreign to my purpose, I shall, as usual, pass them over in silence.

The palace of the Prince of Ottaiano is situated on an eminence above the town, and nearer the mountain, the steps leading up to it, being deeply covered with volcanic matter, resembling the cone of Vesuvius, and the white marble statues on the balustrade made a singular appearance peeping from under the black ashes, which had entirely covered both the balustrade and their pedestals. The roof of the palace was totally destroyed, and the windows were broken; but the house itself, being strongly built, had not suffered much.

We had an opportunity of seeing here exactly the quality of the dreadful shower, as the volcanic matter, which broke through the roof of the palace, and fell into the garrets on the balconies and in the courts, had not been removed. It was composed of the *scoriæ* of fresh lava much vitrified, great and small, mixed with fragments of ancient solid lavas of different sorts; many pieces were enveloped by the new lava, which formed a crust about them; and others were only slightly varnished by the fresh lava. These kind of stones being very compact, and some weighing eight or ten pounds, must have fallen with greater force than the heavier *scoriæ*, which were very porous, and had the great surface above mentioned.

The palace of Ottaiano is built on a thick *stratum* of ancient lava, which ran from the mountain of Somma when in its active volcanic state. Under this *stratum* we were shewn three grottoes, from which issues a constant extreme cold wind, and at times with impetuosity, and a noise like water dashing upon rocks. They are shut up with doors like cellars, and are made use of as such, as also to keep provisions fresh and to cool liquors. I had never seen

these *ventaroli* before. In my letter to Dr. Maty, upon the nature of the soil round Naples, I have mentioned others of the same kind that I had met with on Vesuvius, Etna, and in the island of Ischia*.

We observed, that the tract of country completely covered with a *stratum* of the volcanic matter above-mentioned, was about two miles and a half broad, and as much in length, in which space the vines and fruit trees were totally stripped of their leaves and fruit, and had the appearance of being quite burnt up; but, to my great surprize, having visited that country again two days ago, I saw those very trees, which were apple, pear, peach, and apricot, in blossom again, and some with the fruit already formed, and of the size of hazel-nuts. The vines there had also put forth fresh leaves, and were in bloom. Many foxes, hares, and other game, were destroyed by the fiery shower in the district of Somma and Ottaiano†.

His Sicilian Majesty, whose goodness of heart inclines him on all occasions to shew his benevolence and assist the unfortunate, has ordered a considerable sum of money to be distributed among the unhappy sufferers of Ottaiano and its neighbourhood.

On the 18th of September I went upon Mount Vesuvius, accompanied by Lord Herbert and my usual guide. We could not possibly reach its crater, being covered with a thick smoke, too sulphureous and offensive to be encountered; neither would it have been prudent to have ventured up, had there not been that impediment, as it was evident, from the loud reports we heard from time to time, that there existed still a great fermentation within the bowels of the volcano. We therefore contented ourselves with examining the effects of the late extraordinary eruption on its cone, and in the valley between it and the mountain of Somma.

---

* At Cesi, in the Roman State, towards the Adriatic, there are many such *ventaroli*; and the inhabitants of that town, by means of leaden pipes, conduct the fresh air from them into the very rooms of their houses, so that by turning a cock they can cool them to any degree. Some who have refined still more upon this luxury, by smaller pipes, bring this cold air under the dining table, so as to cool the bottle of liquor upon it.

† Having had the honour of being on a shooting party lately with the King of Naples, at the foot of Vesuvius and Somma, several dead hares were found, and we killed others whose backs were quite bare, the fur having been singed off them by the hot ashes.

The conical part of Vesuvius is now covered with fragments of lava and *scoriæ*, which makes the ascent much more difficult and troublesome than when it was only covered with minute ashes.— The particularity of this last eruption was, that the lava which usually ran out of the flanks of the volcano, forming cascades, rivers, and rivulets of liquid fire, was now chiefly thrown up from its crater in the form of a gigantic fountain of fire,* which falling still in some degree of fusion has, in a manner, cased up the conical part of Vesuvius with a *stratum* of hard *scoriæ;* on the side next the mountain of Somma, that *stratum* is surely more than one hundred feet thick, forming a high ridge. The valley between Vesuvius and Somma has received such a prodigious quantity of lava and other volcanic matter during this last eruption, that it is raised, as is imagined, two hundred and fifty feet or more. Three such eruptions as the last would completely fill up the valley, and by uniting Ve-

* Sorrentino mentions, in his Istoria del Vesuvio, that the volcano in 1676 vented itself in the like manner. "Non a torrenti modo mando fuori le sue viscere, ma tutti in aria menolla." Such wonderful, violent, and sudden emissions of liquid lava must have been occasioned by some accidental and extraordinary cause; and I was inclined to think, that a sudden communication of water with the lava in fusion might be the occasion of such a phenomenon, particularly as we know that pools of rain-water have been found formerly in caverns within the bowels of Vesuvius; and that a river, supposed to be that anciently called Draco, and which was buried by an ancient eruption, burst out some years ago with such force, from under a *stratum* of lava at Torre del Greco, as to be sufficient to turn mills there; but a late curious experiment, mentioned by Mons. de Faujas, in his Recherches sur les Volcans eteints, p. 176, seems to contradict my supposition; and that water introduced to the furnace of a volcano, finding there a more rarified air, would not produce an explosion. Mons. Deslandes, Director of the Royal Manufacture of Looking-glass at St. Gobin, made the following experiment in 1768, in the presence of the Duke de la Rochefoucault, Mons. de Faujas, and others. He poured some water upon a quantity of glass in fusion, and which had been in that state in the crucible for twelve hours. The water did not occasion the least fermentation; but, on the contrary, rolled upon its surface, without even producing any smoke, and after having become seemingly red-hot, like the metal in fusion, disappeared in about three minutes, without having occasioned the least explosion. If the great emissions of lava above mentioned were not then occasioned by water mixing with the lava, may not they have been produced by violent subterraneous exhalations having forced their way into the cauldron of the volcano (if I may be allowed the expression) replete with matter in fusion, and blown its whole contents, with whatever opposed its passage, at once into the air?

suvius and Somma, form them into one mountain, as they most probably were before the great eruption in the reign of Titus. In short, I found the whole face of Vesuvius changed. Those curious channels, in which the lava ran in the month of May last, are all buried. The volcano appears to have likewise increased in height; the form of the crater is changed, a great piece of its rim towards Somma being wanting; and on the side towards the sea it is also broken. There are some very large cracks towards the point of the cone of the volcano, which makes it probable, that more of the borders of the crater will fall in. The ridge of fresh volcanic matter on the cone of Vesuvius towards Somma, and the thick *stratum* in the valley, are likewise full of cracks, from which there issues a constant sulphureous smoke that tinges them and the circumjacent *scoriæ* and cinders with a deep yellow, or sometimes a white tint. These last mentioned cracks, though deep, do not, as I apprehend, pass the *stratum* formed by the last eruption, and which, from its extreme thickness, particularly in the valley, will probably retain a great degree of heat for some years to come, as did a thick *stratum* of lava than ran into *fossa grande* in the year 1767.

The number and size of the stones, or, more properly speaking, of the fragments of lava which have been thrown out of the volcano in the course of the last eruption, and which lie scattered thick on the cone of Vesuvius, and at the foot of it, is really incredible. The largest we measured was in circumference no less than one hundred and eight English feet, and seventeen feet high. It is a solid block, and is much vitrified; in some parts of it there are large pieces of pure glass, of a brown yellow colour, like that of which our common bottles are made, and throughout its pores seem to be filled with perfect vitrifications of the same sort. The spot where it alighted is plainly marked by a deep impression almost at the foot of the cone of the volcano, and it took three bounds before it settled, as is plainly perceived by the marks it has left on the ground, and by the stones which it has pounded to atoms under its prodigious weight. When we consider the enormous size and weight of such a solid mass, thrown at least a quarter of a mile clear of the mouth of the volcano, we can but admire the wonderful powers of nature, of which, being so very seldom within the reach of human inspection, we are in general too apt to judge upon much too small a scale.

Another solid block of ancient lava, sixty-six feet in circumference, and nineteen feet high, being nearly of a spherical shape, was thrown out at the same time, and lies near the former. This stone, which has the marks of having been rounded, nay almost polished, by continual rolling in torrents, or on the sea shore, and which yet has been so undoubtedly thrown out of the volcano, may be the subject of curious speculations*. Another block of solid lava that was thrown much farther, and lies in the valley between the cone of Vesuvius and the Hermitage, is sixteen feet high, and ninety-two feet in circumference, though it plainly appears, by the large fragments that lie round, and were detached from it by the shock of its fall, that it must have been twice as considerable when in the air.

There are thousands of very large fragments of different species of ancient and modern lavas, that lie scattered by the late explosions on the cone of Vesuvius, and in the vallies at its foot; but these three were the largest of those we measured †.

We found also many fragments of those volcanic bombs that burst in the air, as mentioned in the former part of this journal; and some entire, having fallen to the ground without bursting.—The fresh red-hot and liquid lava having been thrown up with numberless fragments of ancient lavas, the latter were often closely enveloped by the former; and probably when such fragments of lava were porous and full of air bubbles, as is often the case, the extreme outward heat, suddenly rarifying the confined air, caused an explosion. When these fragments were of a more compact lava they did not explode, but were simply inclosed by the fresh lava, and acquired a spherical form by whirling in the air, or rolling down the steep sides of the volcano.

The shell or outward coat of the bombs that burst, and of which we found several pieces, was always composed of fresh lava, in

---

* Or may not this stone be a spherical volcanic basalt, such as one of forty-five feet in circumference, described by Mons. Faujas de St. Fond, in p. 155, of his curious book on the subject of extinguished volcanoes?

* We measured two other stones in the valley between Somma and Vesuvius; the one was twenty-two feet and a half long, thirteen feet and a half broad, and ten feet high; the other, eleven feet and a half high, and seventy-two feet in circumference.

which many splinters of the more ancient lava that had been inclosed, are seen sticking. I was much pleased with this discovery, having been greatly puzzled for an explanation of this volcanic operation, which was new to me, and which was very frequent during the eruption of the 9th of August.

The phenomenon of the natural spun glass, which fell at Ottaiano with the ashes on the 5th of August, was likewise clearly explained to me here. I have already mentioned, that the lava thrown up by this eruption was in general more perfectly vitrified than that of any former eruption, which appeared plainly upon a nearer examination of the fragments of fresh lava, the pores of which we generally found full of a pure vitrification, and the *scoriæ* themselves, upon a close examination with a magnifying glass, appeared like a confused heap of filaments of a foul vitrification. When a piece of the solid fresh lava had been cracked in its fall without separating entirely, we always saw capillary fibres of perfect glass, reaching from side to side within the cracks. If I may be allowed a mean comparison, which, however, conveys the idea of what I wish to explain better than any other I can think of, this lava resembled a rich Parmesan cheese, which, when broken and gently separated, spins out transparent filaments from the little cells that contained the clammy liquor of which those filaments were composed. The natural spun-glass, then, that fell at Ottaiano during this eruption, as well as that which fell in the Isle of Bourbon in the year 1766, must have been formed, most probably, by the operation of such a sort of lava as has been just described, cracking and separating in the air at the time of its emission from the craters of the volcanoes, and by that means spinning out the pure vitrified matter from its pores or cells, the wind at the same time carrying off those filaments of glass as fast as they were produced.

I observed, sticking to some very large fragments of the new lava, which were of a close grain, some pieces of a substance, whose texture very much resembled that of a true pumice-stone; and, upon a close examination, and having separated them from the lava, I perceived, that this substance had actually been forced out of the minute pores of the solid stone itself, and was a collection of fine vitreous fibres or filaments, confounded together at the time of their being pressed out by the contraction of the large fragments of lava

in cooling, and which had bent downwards by their own weight. This curious substance has the lightness of a pumice, and resembles it in every respect except being of a darker colour.

When the pores of the fresh solid lava were large and filled with pure vitrified matter, we found that matter sometimes blown into bubbles on its surface, I suppose, by the air which had been forced out at the time the lava contracted itself in cooling: those bubbles, being thin, shewed that this volcanic glass has the kind of transparency of our common glass bottles, and is like them of a dirty yellow colour. I detached with my hammer some large pieces of this kind of glass as big as my fist, which adhered to, and was incorporated with, some of the larger fragments of lava, and, though of the same kind, from their thickness they appeared perfectly black, and were opaque.

Another particularity is remarkable in the lava of this eruption: many detached pieces of it are in the shape of a barley-corn or of a plum-stone, small at each end, and thick in the middle. We picked up several, and saw many more which were too heavy for us to carry off, for they must have weighed more than sixty pounds; some of the smaller ones did not weigh an ounce. I suppose them to be drops from the liquid fountain of fire of the 8th of August, which might very naturally acquire such a form in their fall; but the peasants in the neighbourhood of Vesuvius are well convinced that they are the thunder-bolts that fell with the volcanic lightning.

We found many of the volcanic bombs or, properly speaking, round balls of fresh lava, large and small; all of which have a *nucleus* composed of a fragment of more ancient and solid lava. There were also some other curious vitrifications, very different from any I had ever seen before, mixed with the late fallen shower of huge *scoriæ* and masses of lava.

Though I have endeavoured to be as particular and clear as possible in the description I have given of the curious substances produced by the late eruption of Vesuvius, yet, as specimens of those substances will explain more at one sight than I can pretend to do by whole pages in writing, I shall not fail to send you, by the first favourable opportunity, a collection of them, which I have set apart for that purpose, particularly as, I flatter myself, they may serve to

subterraneous noises heard at times, and by the explosions of scoriæ and ashes, was known to exist within the bowels of the volcano; so that the eruptions of late years, before this last, have, as I have said, been simply from the lava having boiled over the crater, the sides being sufficiently strong to confine it, and oblige it to rise and overflow. The mountain had been remarkably quiet for seven months before its late eruption, nor did the usual smoke issue from its crater, but at times it emitted small clouds of smoke, that floated in the air in the shape of little trees. It was remarked by the Father Antonio di Petrizzi, a capuchin friar (who has printed an account of the late eruption) from his convent close to the unfortunate town of Torre del Greco, that for some days preceding this eruption a thick vapour was seen to surround the mountain, about a quarter of a mile beneath its crater; as it was remarked by him, and others at the same time, that both the sun and the moon had often an unusual reddish cast.

The water of the great fountain at Torre del Greco began to decrease some days before the eruption, so that the wheels of a cornmill, worked by that water, moved very slowly; it was necessary in all the other wells of the town and its neighbourhood to lengthen the ropes daily, in order to reach the water; and some of the wells became quite dry. Although most of the inhabitants were sensible of this phenomenon, not one of them seems to have suspected the true cause of it. It has been well attested, that eight days before the eruption, a man and two boys, being in a vineyard above Torre del Greco (and precisely on the spot where one of the new mouths opened, from whence the principal current of lava that destroyed the town issued), were much alarmed by a sudden puff of smoke that came out of the earth close to them, and was attended with a slight explosion.

Had this circumstance, with that of the subterraneous noises heard at Resina for two days before the eruption (with the additional one of the decrease of water in the wells, as above mentioned) been communicated at the time, it would have required no great foresight to have been certain that an eruption of the volcano was near at hand, and that its force was directed particularly towards that part of the mountain.

On the 12th of June, in the morning, there was a violent fall of rain, and soon after the inhabitants of Resina, situated directly over

the ancient town of Herculaneum, were sensible of a rumbling subterraneous noise, which was not heard at Naples.

From the month of January to the month of May last, the atmosphere was generally calm, and we had continued dry weather. In the month of May we had a little rain, but the weather was unusually sultry. For some days preceding the eruption, the Duke della Torre, a learned and ingenious nobleman of this country, and who has published two letters upon the subject of the late eruption, observed by his electrometers that the atmosphere was charged in excess with the electric fluid, and continued so for several days during the eruption: there are many other curious observations in the duke's account of the late eruption.

About eleven o'clock at night of the 12th June, at Naples we were all sensible of a violent shock of an earthquake; the undulatory motion was evidently from east to west, and appeared to me to have lasted near half a minute. The sky, which had been quite clear, was soon after covered with black clouds. The inhabitants of the towns and villages, which are very numerous at the foot of Vesuvius, felt this earthquake still more sensibly, aud say, that the shock at first was from the bottom upwards, after which followed the undulation from east to west. This earthquake extended all over the Campagna Felice; and their Sicilian majesties were pleased to tell me, that the royal palace at Caserta, which is fifteen miles from this city, and one of the most magnificent and solid buildings in Europe (the walls being eighteen feet thick), was shook in such a manner as to cause great alarm, and that all the chamber-bells rang. It was likewise much felt at Benevento, about thirty miles from Naples; and at Ariano in Puglia, which is at a much greater distance; both these towns have been often afflicted with earthquakes.

On Sunday the 15th of June, soon after ten o'clock at night, another shock of an earthquake was felt at Naples, but did not appear to be quite so violent as that of the 12th, nor did it last so long; at the same moment a fountain of bright fire, attended with a very black smoke and a loud report, was seen to issue, and rise to a great height, from about the middle of the cone of Vesuvius; soon after another of the same kind broke out at some little distance lower down; then, as I suppose from the blowing up of a covered channel full of red-hot lava, it had the appearance as if the lava had taken its course directly up the steep cone of the volcano. Fresh foun-

tains succeeded one another hastily, and all in a direct line tending, for about a mile and a half down, towards the towns of Resina and Torre del Greco. I could count fifteen of them, but I believe there were others obscured by the smoke. It seems probable, that all these fountains of fire, from their being in such an exact line, proceeded from one and the same long fissure down the flanks of the mountain, and that the lava and other volcanic matter forced its way out of the widest parts of the crack, and formed there the little mountains and craters that will be described in their proper place. It is impossible that any description can give an idea of this fiery scene, or of the horrid noises that attended this great operation of nature. It was a mixture of the loudest thunder, with incessant reports, like those from a numerous heavy artillery, accompanied by a continued hollow murmur, like that of the roaring of the ocean during a violent storm; and added to these was another blowing noise, like that of the going up of a large flight of sky-rockets, and which brought to my mind also that noise which is produced by the action of the enormous bellows on the furnace of the Carron iron foundery in Scotland, and which it perfectly resembled. The frequent falling of the huge stones and scoriæ, which were thrown up to an incredible height from some of the new mouths, and one of which having been since measured by the Abbé Tata (who has published an account of this eruption), was ten feet high, and thirty-five in circumference, contributed undoubtedly to the concussion of the earth and air, which kept all the houses at Naples for several hours in a constant tremor, every door and window shaking and rattling incessantly, and the bells ringing. This was an awful moment! The sky, from a bright full moon and star-light, began to be obscured; the moon had presently the appearance of being in an eclipse, and soon after was totally lost in obscurity. The murmur of the prayers and lamentations of a numerous populace forming various processions, and parading in the streets, added likewise to the horror. As the lava did not appear to me to have yet a sufficient vent, and it was now evident that the earthquakes we had already felt had been occasioned by the air and fiery matter confined within the bowels of the mountain, and probably at no small depth (considering the extent of those earthquakes, I recommended to the company that was with me, who began to be much alarmed, rather to go and view the mountain at some greater distance, and in the open air,

than to remain in the house, which was on the sea side, and in the part of Naples that is nearest and most exposed to Vesuvius. We accordingly went to Posilipo, and viewed the conflagration, now become still more considerable, from the sea side under that mountain; but whether from the eruption having increased, or from the loud reports of the volcanic explosions being repeated by the mountain behind us, the noise was much louder, and more alarming than that we had heard in our first position, at least a mile nearer to Vesuvius. After some time, and which was about two o'clock in the morning of the 16th, having observed that the lavas ran in abundance freely, and with great velocity, having made a considerable progress towards Resina, the town which it first threatened, and that the fiery vapours which had been confined had now free vent, through many parts of a crack of more than a mile and a half in length, as was evident from the quantity of inflamed matter and black smoke, which continued to issue from the new mouths abovementioned without any interruption, I concluded that at Naples all danger from earthquakes, which had been my greatest apprehension, was now totally removed, and we returned to our former station at S. Lucia at Naples.

All this time there was not the smallest appearance of fire or smoke from the crater on the summit of Vesuvius; but the black smoke and ashes issuing continually from so many new mouths, or craters, formed an enormous and dense body of clouds over the whole mountain, and which began to give signs of being replete with the electric fluid, by exhibiting flashes of that sort of zig-zag lightning, which in the volcanic language of this country is called *ferilli*, and which is the constant attendant on the most violent eruptions. From what I have read and seen, it appears to me, that the truest judgment that can be formed of the degree of force of the fermentation within the bowels of a volcano during its eruption, would be from observing the size, and the greater or less elevation of those piles of smoky clouds, which rise out of the craters, and form a gigantic mass over it, usually in the form of a pine tree, and from the greater or less quantity of that *ferilli*, or volcanic electricity, with which those clouds appear to be charged.

During thirty years that I have resided at Naples, and in which space of time I have been witness to many eruptions of Vesuvius, of one sort or other, I never saw the gigantic cloud abovementioned

replete with the electric fire, except in the two great eruptions of 1767, that of 1779, and during this more formidable one. The electric fire, in the year 1779, that played constantly within the enormous black cloud over the crater of Vesuvius, and seldom quitted it, was exactly similar to that which is produced, on a very small scale, by the conductor of an electrical machine communicating with an insulated plate of glass, thinly spread over with metallic filings, &c. when the electric matter continues to play over it in zig-zag lines without quitting it. I was not sensible of any noise attending that operation in 1779; whereas the discharge of the electrical matter from the volcanic clouds during this eruption, and particularly the second and third days, caused explosions like those of the loudest thunder; and indeed the storms raised evidently by the sole power of the volcano, resembled in every respect all other thunder storms; the lightning falling and destroying every thing in its course. The house of the Marquis of Berio at S. Iorio, situated at the foot of Vesuvius, during one of these volcanic storms was struck with lightning, which having shattered many doors and windows, and damaged the furniture, left for some time a strong smell of sulphur in the rooms it passed through. Out of these gigantic and volcanic clouds, besides the lightning, both during this eruption and that of 1779, I have, with many others, seen balls of fire issue, and some of a considerable magnitude, which bursting in the air, produced nearly the same effect as that from the air-balloons in fireworks, the electric fire that came out having the appearance of the serpents with which those firework balloons are often filled. The day on which Naples was in the greatest danger from the volcanic clouds, two small balls of fire, joined together by a small link like a chain-shot, fell close to my *casino*, at Posilipo; they separated, and one fell in the vineyard above the house, and the other in the sea, so close to it that I heard a splash in the water; but, as I was writing, I lost the sight of this phenomenon, which was seen by some of the company with me, and related to me as above. The Abbé Tata, in his printed account of this eruption, mentions an enormous ball of this kind which flew out of the crater of Vesuvius whilst he was standing on the edge of it, and which burst in the air at some distance from the mountain, soon after which he heard a noise like the fall of a number of stones, or of a heavy shower of hail.

During the eruption of the 15th at night, few of the inhabitants

of Naples, from the dread of earthquakes, ventured to go to their beds. The common people were either employed in devout processions in the streets, or were sleeping on the quays and open places; the nobility and gentry, having caused their horses to be taken from their carriages, slept in them in the squares and open places, or on the high roads just out of the town. For several days, whilst the volcanic storms of thunder and lightning lasted, the inhabitants at the foot of the volcano, both on the sea side and the Somma side, were often sensible of a tremor in the earth, as well as of the concussions in the air; but at Naples only the earthquakes of the 12th and 15th of June were distinctly and universally felt: this fair city could not certainly have resisted long, had not those earthquakes been fortunately of a short duration. Throughout this eruption, which continued in force about ten days, the fever of the mountain, as has been remarked in former eruptions, shewed itself to be in some measure periodical, and generally was most violent at the break of day, at noon, and at midnight.

About four o'clock in the morning of the 16th, the crater of Vesuvius began to shew signs of being open, by some black smoke issuing out of it; and at daybreak another smoke, tinged with red, issuing from an opening near the crater, but on the other side of the mountain, and facing the town of Ottaiano, shewed that a new mouth had opened there, and from which, as we heard afterwards, a considerable stream of lava issued, and ran with great velocity through a wood, which it burnt; and having run about three miles in a few hours, it stopped before it had arrived at the vineyards and cultivated lands. The crater, and all the conical part of Vesuvius, was soon involved in clouds and darkness, and so it remained for several days; but above these clouds, although of a great height, we could often discern fresh columns of smoke from the crater, rising furiously still higher, until the whole mass remained in the usual form of a pine-tree; and in that gigantic mass of heavy clouds the *ferilli*, or volcanic lightning, was frequently visible, even in the day time. About five o'clock in the morning of the 16th we could plainly perceive, that the lava which had first broke out from the several new mouths on the south side of the mountain, had reached the sea, and was running into it, having overwhelmed, burnt, and destroyed the greatest part of Torre del Greco, the principal stream of lava having taken its course through the very centre of the town. We

observed from Naples, that when the lava was in the vineyards in its way to the town, there issued often, and in different parts of it, a bright pale flame, and very different from the deep red of the lava; this was occasioned by the burning of the trees that supported the vines. Soon after the beginning of this eruption, ashes fell thick at the foot of the mountain, all the way from Portici to the Torre del Greco; and what is remarkable, although there were not at that time any clouds in the air, except those of smoke from the mountain, the ashes were wet, and accompanied with large drops of water, which, as I have been well assured, were to the taste very salt; the road, which is paved, was as wet as if there had been a heavy shower of rain. Those ashes were black and coarse, like the sand of the sea shore, whereas those that fell there, and at Naples some days after, were of a light-grey colour, and as fine as Spanish snuff, or powdered bark. They contained many saline particles; as I observed, when I went to the town of Torre del Greco on the 17th of June, that those ashes that lay on the ground, exposed to the burning sun, had a coat of the whitest powder on their surface, which to the taste was extremely salt and pungent. In the printed account of the late eruption by Emanuel Scotti, doctor of physic and professor of philosophy in the university of Naples, he supposes (which appears to be highly probable) that the water which accompanied the fall of the ashes at the beginning of the eruption, was produced by the mixture of the inflammable and dephlogisticated air, according to experiments made by Doctor Priestley and Monsieur Lavoisier.

By the time that the lava had reached the sea, between five and six o'clock in the morning of the 16th, Vesuvius was so completely involved in darkness, that we could no more discern the violent operation of nature that was going on there, and so it remained for several days; but the dreadful noise we heard at times, and the red tinge on the clouds over the top of the mountain, were evident signs of the activity of the fire underneath. The lava ran but slowly at Torre del Greco after it had reached the sea; and on the 17th of June in the morning, when I went in my boat to visit that unfortunate town, its course was stopped, excepting that at times a little rivulet of liquid fire issued from under the smoking scoriæ into the sea, and caused a hissing noise, and a white vapour smoke; at other times, a quantity of large scoriæ were pushed off the surface of the body of the lava

into the sea, discovering that it was red hot under that surface; and even to this day the centre of the thickest part of the lava that covers the town retains its red heat. The breadth of the lava that ran into the sea, and has formed a new promontory there, after having destroyed the greatest part of the town of Torre del Greco, having been exactly measured by the Duke della Torre, is of English feet 1204. Its height above the sea is twelve feet, and as many feet under water, so that its whole height is twenty-four feet; it extends into the sea six hundred and twenty-six feet. I observed that the sea water was boiling as in a cauldron, where it washed the foot of this new formed-promontory; and although I was at least an hundred yards from it, observing that the sea smoked near my boat, I put my hand into the water, which was literally scalded; and by this time my boatmen observed that the pitch from the bottom of the boat was melting fast, and floating on the surface of the sea, and that the boat began to leak; we therefore retired hastily from this spot, and landed at some distance from the hot lava. The town of Torre del Greco contained about 18000 inhabitants, all of which (except about fifteen, who from either age or infirmity could not be moved, and were overwhelmed by the lava in their houses) escaped either to Castel-a-mare, which was the ancient Stabiæ, or to Naples; but the rapid progress of the lava was such, after it had altered its course from Resina, which town it first threatened, and had joined a fresh lava that issued from one of the new mouths in a vineyard, about a mile from the town, that it ran like a torrent over the town of Torre del Greco, allowing the unfortunate inhabitants scarcely time to save their lives; their goods and effects were totally abandoned, and indeed several of the inhabitants, whose houses had been surrounded with lava whilst they remained in them, escaped from them and saved their lives the following day, by coming out of the tops of their houses, and walking over the scoriæ on the surface of the red-hot lava. Five or six old nuns were taken out of a convent in this manner, on the 16th of June, and carried over the hot lava, as I was informed by the friar who assisted them; and who told me that their stupidity was such, as not to have been the least alarmed, or sensible of their danger: he found one of upwards of ninety years of age actually warming herself at a point of red-hot lava, which touched the window of her cell, and which she said was very comfortable; and though now apprized of their danger, they were

still very unwilling to leave their convent, in which they had been shut up almost from their infancy, their ideas being as limited as the space they inhabited. Having desired them to pack up whatever they had that was most valuable, they all loaded themselves with biscuits and sweetmeats, and it was but by accident that the friar discovered that they had left a sum of money behind them, which he recovered for them; and these nuns are now in a convent at Naples.

At the time I landed at Torre del Greco on the 17th, I found some few of its inhabitants returned, and endeavouring to recover their effects from such houses as had not been thrown down, or were not totally buried under the lava; but alas! what was their cruel disappointment when they found that their houses had been already broke open, and completely gutted of every thing that was valuable; and I saw a scuffle at the door of one house, between the proprietors and the robbers who had taken possession of it. The lava had passed over the centre and best part of the town; no part of the cathedral remained above it, except the upper part of a square brick tower, in which are the bells; and it is a curious circumstance that those bells, although they are neither cracked nor melted, are deprived of their tone as much as if they had been cracked, I suppose by the action of the acid and vitriolic vapours of the lava. Some of the inhabitants of Torre del Greco told me, that when the lava first entered the sea, it threw up the water to a prodigious height; and particularly when two points of lava met and inclosed a pool of water, that then that water was thrown up with great violence, and a loud report: they likewise told me, that at this time, as well as the day after, a great many boiled fish were seen floating on the surface of the sea; and I have since been assured by many of the fishermen of Portici, Torre del Greco, and Torre dell' Annunziata (all of which towns are situated at the foot of Vesuvius), that they could not for many days during the eruption catch a fish within two miles of that coast, which they had evidently deserted.

When this lava is cooled sufficiently, which may not be until some months hence, I shall be curious to examine whether the centre, or solid and compact parts, of the lava that ran into the sea has taken, as it probably may, the prismatical form of basalt columns, like many other ancient lavas disgorged into the water. The exterior of this lava at present, like all others, offers to the eye nothing but a con-

fused heap of loose scoriæ. The lava over the cathedral, and in other parts of the town, is upwards of forty feet in thickness; the general height of the lava during its whole course is about twelve feet, and in some parts not less than a mile in breadth. I walked in the few remaining streets of the town, and I went on the top of one of the highest houses that was still standing, although surrounded by the lava; I saw from thence distinctly the whole course of the lava, that covered the best part of the town; the tops of the houses were just visible here and there in some parts, and the timbers within still burning caused a bright flame to issue out of the surface; in other parts, the sulphur and salts exhaled in a white smoke from the lava, forming a white or yellow crust on the scoriæ round the spots where it issued with the most force. Often I heard little explosions, and saw that they blew up, like little mines, fragments of the scoriæ and ashes into the air; I suppose them to have been occasioned either by rarefied air in confined cellars, or perhaps by small portions of gunpowder taking fire, as few in this country are without a gun and some little portion of gunpowder in their houses. As the church feasts are here usually attended with fireworks and crackers, a firework-maker of this town had a very great quantity of fireworks ready made for an approaching feast, and some gunpowder, all of which had been shut up in his house by the lava, a part of which had even entered one of the rooms; yet he actually saved all his fireworks and gunpowder some days after, by carrying them safely over the hot lava. I should not have been so much at my ease had I known of this gunpowder, and of several other barrels that were at the same time in the cellar of another house, inclosed by the lava, and which were afterwards brought off on women's heads, little thinking of their danger, over the scoriæ of the lava, that was red-hot underneath. The heat in the streets of the town, at this time, was so great as to raise the quicksilver in my thermometer to very near 100 degrees, and close to the hot lava it rose much higher; but what drove me from this melancholy spot was, that one of the robbers with a great pig on his shoulders, pursued by the proprietor with a long gun pointed at him, kept dodging round me to save himself; I bid him throw down the pig and run, which he did; and the proprietor, satisfied with having recovered his loss, acquainted me with my danger, by telling me that there were now thieves in every house that was left standing. I thought it therefore high time

to retire, both for my own safety, and that I might endeavour to procure from Naples some protection for the doubly unfortunate sufferers of this unhappy town. Accordingly I returned to Naples in my boat, and immediately acquainted this government with what I had just seen myself; in consequence of which a body of soldiers was sent directly to their relief by sea, the road by land having been cut off by the lava. I remarked in my way home, that there was a much greater quantity of the petroleum floating on the surface of the sea, and diffusing a very strong and offensive smell, than was usual; for at all times in calms, patches of this bituminous oil, called here petroleum, are to be seen floating on the surface of the sea between Portici and Naples, and particularly opposite a village called Pietra Bianca. The minute ashes continued falling all this day at Naples; the mountain, continually obscured by them, continued to alarm us with repeated loud explosions; the streets of this city were this day and the next constantly filled with religious and penetential processions, composed of all classes, and nothing was heard in the midst of darkness but the thunder of the mountain, and *ora pro nobis*. The sea wind increasing at times, delivered us from these ashes, which it scattered over different parts of the Campagna Felice.

On Wednesday the 18th, the wind having for a short space of time cleared away the thick cloud from the top of Vesuvius, we discovered that a great part of its crater, particularly on the west side opposite Naples, had fallen in, which it probably did about four o'clock in the morning of this day, as a violent shock of an earthquake was felt at that moment at Resina, and other parts situated at the foot of the volcano. The clouds of smoke, mixed with the ashes which, as I have before remarked, were as fine as Spanish snuff (so much so that the impression of a seal with my coat of arms would remain distinctly marked upon them), were of such a density as to appear to have the greatest difficulty in forcing their passage out of the now widely extended mouth of Vesuvius, which certainly, since the top fell in, cannot be much short of two miles in circumference. One cloud heaped on another, and succeeding one another incessantly, formed in a few hours such a gigantic and elevated column of the darkest hue over the mountain, as seemed to threaten Naples with immediate destruction, having at one time been bent over the city, and appearing to be much too massive and ponderous

to remain long suspended in the air; it was besides replete with the *ferilli*, or volcanic lightnight, which was stronger than common lightning, just as Pliny the younger describes it in one of his letters to Tacitus, when he says *fulgoribus illæ et similes et majores erant.*

Vesuvius was at this time completely covered, as were all the old black lavas, with a thick coat of these fine light-grey ashes already fallen, which gave it a cold and horrid appearance; and in comparison of the abovementioned enormous mass of clouds, which certainly, however it may contradict our idea of the extension of our atmosphere, rose many miles above the mountain, it appeared like a mole-hill; although, as you know, Sir, the perpendicular height of Vesuvius from the level of the sea, is more than three thousand six hundred feet. The Abbé Braccini, as appears in his printed account of the eruption of Mount Vesuvius in 1631, measured with a quadrant the elevation of a mass of clouds of the same nature, that was formed over Vesuvius during that great eruption, and found it to exceed thirty miles in height. Doctor Scotti, in his printed account of this eruption, says, that the height of this threatening cloud of smoke and ashes, measured (but he does not say how) from Naples, was found to be of an elevation of thirty degrees. All I can say is, that to my eye the distance from the crater of Vesuvius to the most elevated part of the cloud, appeared to me nearly the same as that of the island of Caprea from Naples, and which is about twenty-five miles; but I am well aware of the inaccuracy of such a sort of measurement.

I must own, that at that moment I did apprehend Naples to be in some danger of being buried under the ashes of the volcano, just as the towns of Herculaneum and Pompeii were in the year 79. The ashes that fell then at Pompeii were of the same fine quality as those from this eruption; having often observed, when present at the excavations of that ancient city, that the ashes, which I suppose to have been mixed with water at the same time, had taken the exact impression or mould of whatever they had inclosed; so that the compartments of the wood work of the windows and doors of the houses remained impressed on this volcanic tufa, although the wood itself had long decayed, and not an atom of it to be seen, except when the wood had been burnt, and then you found the charcoal. Having once been present at the discovery of a skeleton in the great

street of Pompeii, of a person who had been shut up by the ashes during the eruption of 79, I engaged the men that were digging to take off the piece of hardened tufo, that covered the head, with great care, and, as in a mould just taken off in plaster of Paris, we found the impression of the eyes, that were shut, of the nose, mouth, and of every feature perfectly distinct. A similar specimen of a mould of this kind, brought from Pompeii, is now in his Sicilian Majesty's museum at Portici; it had been formed over the breast of a young woman that had been shut up in the volcanic matter; every fold of a thin drapery that covered her breast is exactly represented in this mould: and in the volcanic tufo that filled the ancient theatre of Herculaneum, the exact mould or impression of the face of a marble bust is still to be seen, the bust or statue having been long since removed. Having observed these fine ashes issuing in such abundance from Vesuvius, and having the appearance of being damp or wet, that they do not take such beautiful forms and volutes as a fine dry smoke usually does, but appear in hard and stiff little curls, you will not wonder then, that the fate of Herculaneum and Pompeii should have come again strongly into my mind; but fortunately the wind sprung up fresh from the sea, and the threatening cloud bent gradually from us over the mountain of Somma, and involved all that part of the Campagna in obscurity and danger.

To avoid prolixity and repetition, I need only say, that the storms of thunder and lightning, attended at times with heavy falls of rain and ashes, causing the most destructive torrents of water and glutinous mud, mixed with huge stones, and trees torn up by the roots, continued more or less to afflict the inhabitants on both sides of the volcano until the 7th of July, when the last torrent destroyed many hundred acres of cultivated land, between the towns of Torre del Greco and Torre dell' Annunziata. Some of these torrents, as I have been credibly assured by eye witnesses, both on the sea side and the Somma side of the mountain, came down with a horrid rushing noise; and some of them, after having forced their way through the narrow gullies of the mountain, rose to the height of more than twenty feet, and were near half a mile in extent. The mud of which the torrents were composed, being a kind of natural mortar, has completely cased up, and ruined for the present, some thousand acres of rich vineyards; for it soon becomes so hard, that nothing less than a pick-axe can break it up; I say for the present,

as I imagine that hereafter the soil may be greatly improved by the quantity of saline particles that the ashes from this eruption evidently contain. A gentleman of the British factory at Naples, having filled a plate with the ashes that had fallen on his balcony during the eruption, and sowed some pease in them, assured me that they came up the third day, and that they continue to grow much faster than is usual in the best common garden soil.

My curiosity, or rather my wish to gratify that of our respectable Society, induced me to go upon Mount Vesuvius, as soon as I thought I might do it with any degree of prudence, which was not until the 30th of June, and then it was attended with some risk, as will appear in the course of this narrative. The crater of Vesuvius, except at short intervals, had been continually obscured by the volcanic clouds ever since the 16th, and was so this day, with frequent flashes of lightning playing in those clouds, and attended as usual with a noise like thunder; and the fine ashes were still falling on Vesuvius, but still more on the mountain of Somma. I went up the usual way by Resina, attended by my old Cicerone of the mountain, Bartolomeo Pumo, with whom I have been sixty-eight times on the highest point of Vesuvius. I observed in my way through the village of Resina that many of the stones of the pavement had been loosened, and were deranged by the earthquakes, particularly by that of the 18th, which attended the falling-in of the crater of the volcano, and which as they told me there, had been so violent as to throw many people down, and obliged all the inhabitants of Resina to quit their houses hastily, and to which they did not dare return for two days. The leaves of all the vines were burnt by the ashes that had fallen on them, and many of the vines themselves were buried under the ashes, and great branches of the trees that supported them had been torn off by their weight. In short, nothing but ruin and desolation was to be seen. The ashes at the foot of the mountain were about ten or twelve inches thick on the surface of the earth, but in proportion as we ascended their thickness increased to several feet, I dare say not less than nine or ten in some parts; so that the surface of the old rugged lavas, that before was almost impracticable, was now become a perfect plain, over which we walked with the greatest ease. The ashes were of a light-grey colour, and exceedingly fine, so that by the footsteps being marked on them as on snow, we learnt

that three small parties had been up before us. We saw likewise the track of a fox, that appeared to have been quite bewildered, to judge from the many turns he had made. Even the traces of lizards and other little animals, and of insects, were visible on these fine ashes. We ascended to the spot whence the lava of the 15th first issued, and we followed the course of it, which was still very hot (although covered with such a thick coat of ashes), quite down to the sea at Torre del Greco, which is more than five miles. A pair of boots, to which I had for the purpose added a new and thick sole, were burnt through on this expedition. It was not possible to get up to the great crater of Vesuvius, nor had any one yet attempted it. The horrid chasms that exist from the spot where the late eruption first took place, in a straight line for near two miles towards the sea, cannot be imagined. They formed vallies more than two hundred feet deep, and from half to a mile wide; and where the fountains of fiery matter existed during the eruption, are little mountains with deep craters. Ten thousand men, in as many years, could not, surely, make such an alteration on the face of Vesuvius, as has been made by nature in the short space of five hours. Except the exhalations of sulphureous and vitriolic vapours, which broke out from different spots of the line abovementioned, and tinged the surface of the ashes and scoriæ in those parts with either a deep or pale yellow with a reddish ochre colour, or a bright white, and in some parts with a deep green and azure blue (so that the whole together had the effect of an iris), all around us had the appearance of a sandy desert. We went on the top of seven of the most considerable of the new-formed mountains, and looked into their craters, which on some of them appeared to be little short of half a mile in circumference; and although the exterior perpendicular height of any of them did not exceed two hundred feet, the depth of their inverted cone within was three times as great. It would not have been possible for us to have breathed on these new mountains near their craters, if we had not taken the precaution of tying a doubled handkerchief over our mouths and nostrils; and even with that precaution we could not resist long, the fumes of the vitriolic acid were so exceedingly penetrating, and of such a suffocating quality. We found in one a double crater, like two funnels joined together; and in all there was some little smoke and depoi-

tions of salts and sulphurs, of the various colours abovementioned, just as is commonly seen adhering to the inner walls of the principal crater of Vesuvius.

Two or three days after we had been here, one of the new mouths into which we had looked, suddenly made a great explosion of stones, smoke, and ashes, which would certainly have proved fatal to any one who might unfortunately have been there at the time of the explosion. We read of a like accident having proved fatal to more than twenty people, who had the curiosity to look into the crater of the Monte Nuovo, near Pozzuoli, a few days after its formation, in the year 1538. The 15th of August, I saw a sudden explosion of smoke and ashes, thrown to an extreme height out of the great crater of Vesuvius, that must have destroyed any one within half a mile of it; and yet on the 19th of July a party not only had visited that crater, but had descended 170 feet within it. Whilst we were on the mountain, two whirlwinds, exactly like those that form water-spouts at sea, made their appearance; and one of them that was very near us made a strange rushing noise, and having taken up a great quantity of fine ashes, formed them into an elevated spiral column, which, with a whirling motion and great rapidity, was carried towards the mountain of Somma, where it broke and was dispersed. As there were evident signs of an abundance of electricity in the air at this time, I have no doubt of this having been also an electrical operation. One of my servants, employed in collecting of sulphur, or sal ammoniac, which crystallizes near the *fumaroli*, as they are called here (and which are the spots from whence the hot vapour issues out of the fresh lava), found to his great surprise an exceeding cold wind issue from a fissure very near the hot *fumaroli* abovementioned upon his leg; I put my hand to the spot, and found the same; but it did not surprise me, as before on Mount Vesuvius, on the mountain of Somma, on Mount Etna, and in the island of Ischia, I had met with, on particular spots, the like currents of extreme cold air issuing from beneath the ancient lavas, and which, being constant to those spots, are known by the name of *ventoroli*. In a vineyard not in the same line with the new-formed mountains just described, but in a right line from them, at the distance of little more than a mile from Torre del Greco, are three or four more of these new-formed mountains with craters, out of which the lava flowed, and by uniting with the streams that came

from the higher mouths, and adding to their heat and fluidity, enabled the whole current to make so rapid a progress over the unfortunate town, as scarcely to allow its inhabitants sufficient time to escape with their lives. The rich vineyards belonging to the Torre del Greco, and which produced the good wine called *Lacrima Christi*, that have been buried, and are totally destroyed by this lava, consisted, as I have been informed, of more than three thousand acres; but the destruction of the vineyards by the torrents of mud and water at the foot of the mountain of Somma, is much more extensive.

I visited that part of the country also a few days after I had been on Vesuvius, not being willing to relate to you any one circumstance of the late formidable eruption but what I had reason to believe was founded on truth. The first signs of a torrent that I met with, was near the village of the Madonna dell' Arco, and I passed several others between that and the town of Ottaiano; the one near Trochia, and two near the town of Somma, were the most considerable, and not less than a quarter of a mile in breadth; and as several eye-witnesses assured me on the spot, were, when they poured down from the mountain of Somma, from twenty to thirty feet high; it was a liquid glutinous mud, composed of scoriæ, ashes, stones (some of which of an enormous size) mixed with trees that had been torn up by the roots. Such torrents, as you may well imagine, were irresistible, and carried all before them; houses, walls, trees, and, as they told me, not less than four thousand sheep and other cattle, had been swept off by the several torrents on that side of the mountain. At Somma they likewise told me that a team of eight oxen, that were drawing a large timber tree, had been carried off from thence, and never were more heard of.

The appearance of these torrents, when I saw them, was like that of all other torrents in mountainous countries, except that what had been mud was become a perfect cement, on which nothing less than a pick-axe could make any impression. The vineyards and cultivated lands were here much more ruined; and the limbs of the trees much more torn by the weight of the ashes, than those which I have already described on the sea side of the volcano.

The Abbé Tata, in his printed account of this eruption, has given a good idea of the abundance, the great weight, and glutinous quality of these ashes, when he says that having taken a branch

from a fig-tree still standing near the town of Somma, on which were only six leaves, and two little unripe figs, and having weighed it with the ashes attached to it, he found it to be thirty-one ounces; when having washed off the volcanic matter, it scarcely weighed three ounces.

I saw several houses on the road, in my way to the town of Somma, with their roofs beaten in by the weight of the ashes. In the town of Somma, I found four churches and about seventy houses without roofs, and full of ashes. The great damage on this side of the mountain, by the fall of the ashes and the torrents, happened on the 18th, 19th, and 20th of June, and on the 12th of July. I heard but of three lives that had been lost at Somma by the fall of a house. The 19th, the ashes fell so thick at Somma (as they told me there), that unless a person kept in motion, he was soon fixed to the ground by them. This fall of ashes was accompanied also with loud reports, and frequent flashes of the volcanic lightning, so that, surrounded by so many horrors, it was impossible for the inhabitants to remain in the town, and they all fled; the darkness was such, although it was mid-day, that even with the help of torches it was scarcely possible to keep in the high road; in short, what they decribed to me was exactly what Pliny the younger and his mother had experienced at Misenum during the eruption of Vesuvius in the reign of Titus, according to his second letter to Tacitus on that subject. I found that the majority of people here were convinced that the torrents of mud and water, that had done them so much mischief, came out of the crater of Vesuvius, and that it was sea-water; but there cannot be any doubt of those floods having been occasioned by the sudden dissolution of watery clouds mixed with ashes, the air perhaps having been too much rarefied to support them; and when such clouds broke and fell heavily on Vesuvius, the water not being able to penetrate as usual into the pores of the earth, which were then filled up with the fine ashes of a bituminous and oily quality, nor having free access to the channels which usually carried it off, accumulated in pools, and mixing with more ashes, rose to a great height, and at length forced its way through new channels, and came down in torrents over countries where it was least expected, and spread itself over the fertile lands at the foot of the mountain. From what I have seen lately, I begin to doubt very much if the water, by which so much damage was

done, and so many lives were lost during the terrible eruption of Vesuvius in 1631, did really, as was generally supposed, come out of the crater of the volcano: sentiments were divided then, as they are now, on that subject; and since in all great eruptions the crater of the volcano must be obscured by the clouds of ashes, as it probably was then, and certainly was during the violence of the late eruption, therefore it must be very difficult to ascertain exactly from whence that water came. The more extraordinary a circumstance is, the more it appears to be the common desire that it should be credited; from this principle, one of his Sicilian Majesty's gardeners of Portici, went up to the crater of Vesuvius as soon as it was practicable, and came down in a great fright, declaring that he had seen it full of boiling water. The Chevalier Macedonio, intendant of Portici, judged very properly, that to put an end to the alarm this report had spread over the country, it was necessary to send up people he could trust, and on whose veracity he might depend. Accordingly the next day, which was the 16th of July, Signor Guiseppe Sacco went up, well attended, and proved the gardener's assertion to be absolutely false, there being only some little signs of mud from a deposition of the rain water at the bottom of the crater. According to Sacco's account, which has been printed at Naples, the crater is of an irregular oval form, and, as he supposes (not having been able to measure it) of about a mile and a half in circumference; by my eye I should judge it to be more; the inside, as usual, in the shape of an inverted cone, the inner walls of which on the eastern side are perpendicular; but on the western side of the crater, which is much lower, the descent was practicable, and Sacco with some of his companions actually went down 176 palms, from which spot, having lowered a cord with a stone tied to it, they found the whole depth of the crater to be about 500 palms. But such observations on the crater of Vesuvius are of little consequence, as both its form and apparent depth are subject to great alterations from day to day. These curious observers certainly ran some risk at that time, since which such a quantity of scoriæ and ashes have been thrown up from the crater, and even so lately as the 15th of this month, as must have proved fatal to any one within their reach.

The 22d of July, one of the new craters, which is the nearest to the town of Torre del Greco, threw up both fire and smoke, which

circumstance, added to that of the lava's retaining its heat much longer than usual, seems to indicate that there may still be some fermentation under that part of the volcano. The lava in cooling often cracks, and causes a loud explosion, just as the ice does in the Glaciers in Switzerland; such reports are frequently heard now at the Torre del Greco; and as some of the inhabitants told me, they often see a vapour issue from the body of the lava, and taking fire in the air, fall like those meteors vulgarly called falling stars.

The darkness occasioned by the fall of the ashes in the Campagna Felice extended itself, and varied, according to the prevailing winds. On the 19th of June it was so dark at Caserta, which is fifteen miles from Naples, as to oblige the inhabitants to light candles at mid-day; and one day during the eruption, the darkness spread over Benevento, which is thirty miles from Vesuvius.

The Archbishop of Taranto, in a letter to Naples, and dated from that city the 18th of June, said, "We are involved in a thick cloud of minute volcanic ashes, and we imagine that there must be a great eruption either of Mount Etna, or of Stromboli." The bishop did not dream of their having proceeded from Vesuvius, which is about 250 miles from Taranto. We have had accounts also of the fall of the ashes during the late eruption at the very extremity of the province of Lecce, which is still farther off; and we have been assured likewise, that those clouds were replete with electrical matter: at Martino, near Taranto, a house was struck and much damaged by the lightning from one of these clouds. In the accounts of the great eruption of Vesuvius in 1631, mention is made of the extensive progress of the ashes from Vesuvius, and of the damage done by the *ferilli*, or volcanic lightning, which attended them in their course.

I must here mention a very extraordinary circumstance indeed, that happened near Sienna in the Tuscan state, about eighteen hours after the commencement of the late eruption of Vesuvius on the 15th of June, although that phænomenon may have no relation to the eruption; and which was communicated to me in the following words by the Earl of Bristol, bishop of Derry, in a letter dated from Sienna, July 12th, 1794: "In the midst of a most violent thunderstorm, about a dozen stones of various weights and dimensions fell at the feet of different people, men, women, and children; the stones are of a quality not found in any part of the Siennese terri-

tory; they fell about eighteen hours after the enormous eruption of Vesuvius, which circumstance leaves a choice of difficulties in the solution of this extraordinary phænomenon: either these stones have been generated in this igneous mass of clouds, which produced such unusual thunder, or, which is equally incredible, they were thrown from Vesuvius at a distance of at least 250 miles; judge then of its parabola. The philosophers here incline to the first solution. I wish much, Sir, to know your sentiments. My first objection was to the fact itself; but of this there are so many eye-witnesses, it seems impossible to withstand their evidence, and now I am reduced to a perfect scepticism." His lordship was pleased to send me a piece of one of the largest stones, which when entire, weighed upwards of five younds; I have seen another that has been sent to Naples entire, and weighs about one pound. The outside of every stone that has been found, and has been ascertained to have fallen from the cloud near Sienna, is evidently freshly vitrified, and is black, having every sign of having passed through an extreme heat; when broken, the inside is of a light-grey colour mixed with black spots, and some shining particles, which the learned here have decided to be pyrites, and therefore it cannot be a lava, or they would have been decomposed. Stones of the same nature, at least as far as the eye can judge of them, are frequently found on Mount Vesuvius; and when I was on the mountain lately, I searched for such stones near the new mouths, but as the soil round them has been covered with a thick bed of fine ashes, whatever was thrown up during the force of the eruption lies buried under those ashes. Should we find similar stones with the same vitrified coat on them on Mount Vesuvius, as I told Lord Bristol in my answer to his letter, the question would be decided in favour of Vesuvius; unless it could be proved that there had been, about the time of the fall of these stones in the Sanese territory, some nearer opening of the earth, attended with an emission of volcanic matter, which might very well be, as the mountain of Radicofani, within fifty miles of Sienna, is certainly volcanic. I mentioned to his lordship another idea that struck me. As we have proofs during the late eruption of a quantity of ashes of Vesuvius having been carried to a greater distance than where the stones fell in the Sanese territory, might not the same ashes have been carried over the Sanese territory, and mixing with a stormy cloud, have been collected together just as

hailstones are sometimes into lumps of ice, in which shape they fall; and might not the exterior vitrification of those lumps of accumulated and hardened volcanic matter have been occasioned by the action of the electric fluid on them? The celebrated Father Ambrogio Soldani, professor of mathematics in the university of Sienna, is printing there his dissertation upon this extraordinary phenomenon; wherein, as I have been assured, he has decided that those stones were generated in the air independently of volcanic assistance.

Until after the 7th of July, when the last cloud broke over Vesuvius, and formed a tremendous torrent of mud, which took its course across the great road between Torre del Greco and the Torre dell' Annunziata, and destroyed many vineyards, the late eruption could not be said to have finished, although the force of it was over the 22d of June, since which time the crater has been usually visible. The power of attraction in mountains is well known; but whether the attractive power of a volcanic mountain be greater than that of any other mountain, is a question: all I can say is, that during this last eruption every watery cloud has been evidently attracted by Vesuvius, and the sudden dissolution of those clouds has left such marks of their destructive power on the face of the country all round the basis of the volcano as will not soon be erased. Since the mouth of Vesuvius has been enlarged, I have seen a great cloud passing over it, and which not only was attracted, but was sucked in, and disappeared in a moment.

After every violent eruption of Mount Vesuvius, we read of damage done by a mephitic vapour, which coming from under the ancient lavas, insinuates itself into low places, such as the cellars and wells of the houses situated at the foot of the volcano. After the eruption of 1767, I remember that there were several instances, as in this, of people going into their cellars at Portici, and other parts of that neighbourhood, having been struck down by this vapour, and who would have expired if they had not been hastily removed. These occasional vapours, and which are called here *mofete*, are of the same quality as that permanent one in the Grotta del Cane, near the lake of Agnano, and which has been proved to be chiefly fixed air. The vapours, that in the volcanic language of this country are called *fumaroli*, are of another nature, and issue from spots all over the fresh and hot lavas whilst they are cooling; they

are sulphureous and suffocating, so much so that often the birds that are flying over them are overpowered, and fall down dead; of which we have had many examples during this eruption, particularly of wood pigeons, that have been found dead on the lava. These vapours deposit a crust of sulphur, or salts, particularly of sal ammoniac, on the scoriæ of the lava through which they pass; and the small crystals of which they are composed are often tinged with a deep or pale yellow, with a bright red like cinnabar, and sometimes with green, or an azure blue. Since the late eruption, many pieces of the scoriæ of the fresh lava have been found powdered with a lucid substance, exactly like the brightest steel or iron filings.

The first appearance of the *mofete*, after the late eruption, was on the 17th of June, when a peasant going with an ass to his vineyard, a little above the village of Resina, in a narrow hollow way, the ass dropped down, and seemed to be expiring; the peasant was soon sensible of the mephitic vapour himself, and well knowing its fatal effects, dragged the animal out of its influence, and it soon recovered. From that time these vapours have greatly increased, and extended themselves. There are to this day many cellars and wells, all the way from Portici to Torre dell' Annunziata, greatly affected by them. This heavy vapour, when exposed to the open air, does not rise much more than a foot above the surface of the earth, but when it gets into a confined place, like a cellar or well, it rises and fills them as any other fluid would do; having filled a well, it rises above it about a foot high, and then bending over, falls to the earth, on which it spreads, always preserving its usual level. Wherever this vapour issues, a wavering in the air is perceptible, like that which is produced by the burning of charcoal; and when it issues from a fissure near any plants or vegetables, the leaves of those plants are seen to move, as if they were agitated by a gentle wind. It is extraordinary, that although there does not appear to be any poisonous quality in this vapour, which in every respect resembles fixed air, it should prove so very fatal to the vineyards, some thousand acres of which have been destroyed by it since the late eruption; when it penetrates to the roots of the vines, it dries them up, and kills the plant. A peasant in the neighbourhood of Resina having suffered by the *mofete*, which destroyed his vineyards in the year 1767, and having observed then that the vapour followed the laws of all fluids, made a narrow deep ditch all round his vineyard, which

communicated with ancient lavas, and also to a deep cavern under one of them; the consequence of his well-reasoned-operation has been, that although surrounded at present by these noxious vapours, and which lie constantly at the bottom of his ditch, they have never entered his vineyard, and his vines are now in a flourishing state, whilst those of his neighbours are perishing. Upwards of thirteen hundred hares, and may pheasants and partridges, overtaken by this vapour, have been found dead within his Sicilian majesty's reserved chases in the neighbourhood of Vesuvius; and also many domestic cats, who in their pursuit after this game, fell victims to the *mofete.* A few days ago a shoal of fish, of several hundred weight, having been observed by some fishermen at Resina in great agitation on the surface of the sea, near some rocks of an ancient lava that had run into the sea, they surrounded them with their nets, and took them all with ease, and afterwards discovered that they had been stunned by the mephitic vapour, which at that time issued forcibly from underneath the ancient lava into the sea. I have been assured by many fishermen, that during the force of the late eruption the fish had totally abandoned the coast from Portici to the Torre dell' Annunziata, and that they could not take one in their nets nearer the shore than two miles. The divers there, who fish for the *ancini* (which we call sea-eggs) and other shell fish, likewise told me, that for the space of a mile from that shore, since the eruption, they have found all the fish dead in their shells, as they suppose either from the heat of the sand at the bottom of the sea, or from poisonous vapours. The divers at Naples complain of their finding also many of these shell fish, or as they are called here in general terms *frutti di mare,* dead in their shells.

I thought that these little well attested facts might contribute to show the great force of the wonderful chemical operation of nature that has lately been exhibited here. The *mofette,* or fixed-air vapours, must certainly have been generated by the action of the vitriolic acid upon the calcareous earth, as both abound in Vesuvius. The sublimations, which are visibly operating by the chemistry of nature all along the course of the last lava that ran from Vesuvius, and particularly in and about the new mouths that have been formed by the late eruption on the flanks of the volcano, having been analyzed by Signor Domenico Tomaso, an ingenious chemist of Naples, and whose experiments, and the result of them, are now published,

have been found to be chiefly sal ammoniac, mixed with a small quantity of the calx of iron: but not to betray my ignorance on this subject, and pretending to nothing more than the being an exact ocular observer, I refer you to the work itself, which accompanies this letter. Many hundred weight of the Vesuvian sal ammoniac have been collected on the mountain since the late eruption by the peasants, and sold at Naples to the refiners of metals; at first it was sold for about sixpence a pound, but, from its abundance, the price is now reduced to half that money; and a much greater quantity must have escaped in the air by evaporation.

The situation of Mount Vesuvius so near a great capital, and the facility of approaching it, has certainly afforded more opportunities of watching the operations of an active volcano, and of making observations upon it, than any other volcano on the face of the earth has allowed of. The Vesuvian Diary, which by my care has now been kept with great exactness, and without interruption for more than fifteen years, by the worthy and ingenious Padre Antonio Piaggi, as mentioned in the beginning of this letter, and which it is my intention to deposit in the library of the Royal Society, will also throw a great light upon this curious subject. But as there is every reason to believe, with Seneca *, that the seat of the fire that causes these eruptions of volcanoes is by no means superficial, but lies deep in the bowels of the earth, and where no eye can penetrate, it will, I fear, be ever much beyond the reach of the limited human understanding to account for them with any degree of accuracy. There are modern philosophers who propose, with as great confidence, the erecting of conductors to prevent the bad effects of earthquakes and volcanoes, and who promise themselves the same success as that which attended Dr. Franklin's conductors of lightning; for, as they say, all proceed from one and the same cause, electricity. When we reflect how many parts of the earth already inhabited have evidently been thrown up from the bottom of the sea by volcanic explosions, and the probability of there being a much greater portion under the same predicament, as yet unexplored, the vain pretensions of weak mortals to counteract such great operations, carried on surely for the

* "Non ipse ex se est, sed in aliqua inferna valle conceptus exæstuat, et "alibi pascitur; *in ipso monte non alimentum habet, sed viam.*"—Seneca, Epist. 79.

wisest purposes by the beneficent Author of nature, appear to me to be quite ridiculous.

Let us then content ourselves with seeing, as well as we can, what we are permitted to see, and reason upon it to the best of our limited understandings, well assured that whatever is, is right.

The late sufferers at Torre del Greco, although His Sicilian Majesty, with his usual clemency, offered them a more secure spot to rebuild their town on, are obstinately employed in rebuilding it on the late and still smoking lava that covers their former habitations; and there does not appear to be any situation more exposed to the numerous dangers that must attend the neighbourhood of an active volcano than that of Torre del Greco. It was totally destroyed in 1631; and in the year 1737 a dreadful lava ran within a few yards of one of the gates of the town, and now over the middle of it; nevertheless, such is the attachment of the inhabitants to their native spot, although attended with such imminent danger, that of 18,000 not one gave his vote to abandon it. When I was in Calabria, during the earthquakes of 1783, I observed in the Calabrese the same attachment to native soil; some of the towns that were totally destroyed by the earthquakes, and which had been ill situated in every respect, and in a bad air, were to be rebuilt; and yet it required the authority of government to oblige the inhabitants of those ruined towns to change their situation for a much better.

Upon the whole, having read every account of the former eruptions of Mount Vesuvius, I am well convinced that this eruption was by far the most violent that has been recorded after the great eruptions of 79 and 1631, which were undoubtedly still more violent and destructive. The same phenomenon attended the last eruption as the two former abovementioned, but on a less scale, and without the circumstance of the sea having retired from the coast. I remarked more than once, whilst I was in my boat, an unusual motion in the sea during the late eruption. On the 18th of June I observed, and so did my boatman, that although it was a perfect calm, the waves suddenly rose and dashed against the shore, causing a white foam, but which subsided in a few minutes. On the 15th, the night of the great eruption, the corks that support the nets of the royal tunny fishery at Portici, and which usually float upon the surface of the sea, were suddenly drawn under water, and remained so for a short space of time, which indicates, that either there must have

been at that time a swell in the sea, or a depression or sinking of the earth under it.

From what we have seen lately here, and from what we read of former eruptions of Vesuvius, and of other active volcanoes, their neighbourhood must always be attended with danger; with this consideration, the very numerous population at the foot of Vesuvius is remarkable. From Naples to Castel-a-mare, about fifteen miles is so thickly spread with houses as to be nearly one continued street, and on the Somma side of the volcano, the towns and villages are scarcely a mile from one another; so that for thirty miles, which is the extent of the basis of Mount Vesuvius and Somma, the population may be perhaps more numerous than that of any spot of a like extent in Europe, in spite of the variety of dangers attending such a situation.

With the help of the drawings that accompany this account of the late eruption of Vesuvius, and which I can assure you to be faithful representations of what we have seen, I flatter myself I shall have enabled you to have a clear idea of it; and I flatter myself also, that the communication of such a variety of well attested phænomena as have attended this formidable eruption, may not only prove acceptable, but useful to the curious in natural history.

In a subsequent letter from Sir William Hamilton to Sir Joseph Banks, dated Castel-a-mare, anciently Stabiæ, Sept. 2, 1794, are the two following remarks, to be added to this paper.

1. Within a mile of this place the *mofete* are still very active, and particularly under the spot where the ancient town of Stabiæ was situated. The 24th of August, a young lad by accident falling into a well there that was dry, but full of the mephitic vapour, was immediately suffocated; there were no signs of any hurt from the fall, as the well was shallow. This circumstance called to my mind the death of the elder Pliny, who most probably lost his life by the same sort of mephitic vapours, on this very spot, and which are active after great eruptions of Vesuvius.

2. Mr. James, a British merchant, who now lives in this neighbourhood, assured me that on Tuesday night, the 17th of June, which was the third day after the eruption of Mount Vesuvius, he was in a boat with a sail, near Torre del Greco, when the minute

SUMMIT OF MOUNT ETNA.

ashes, so often mentioned in my letter, fell thick; and that in the dark they emitted a pale light like phosphorus, so that his hat, those of the boatmen, and the part of the sails that were covered with the ashes, were luminous. Others have mentioned to me the having seen a phosphoric light on Vesuvius after this eruption; but until it was confirmed to me by Mr. James, I did not choose to say any thing about it.

[*Phil. Trans.* 1795.]

CHAP. X.

ETNA AND ITS ERUPTIONS.

Sect. 1.—*General History.*

We have purposely dwelt with considerable minuteness upon the volcanic phænomena of Vesuvius in the preceding chapter, not only because they have been more explicitly detailed than those of any similar mountain, but that we might bring the history of this class of natural wonders as much as possible into one form. In the volcanoes which we shall yet think it our duty to describe, we shall endeavour to confine ourselves to the peculiar and prominent features by which every one is distinguished from every other.

Etna is the most striking phænomenon of the island of Sicily; and though less frequently delineated than Vesuvius, is so much more gigantic, that the latter, if placed by the side of it, would seem nothing more than a small ejected hill, and is in fact not longer than several of the mountains by which it is surrounded. The whole circuit of the base of Vesuvius does not exceed thirty miles, while Etna covers a space of a hundred and eighty miles, and its height above the level of the sea is computed at not less than eleven thousand feet; and while the lava of the first not often devolves its stream further than to an extent of seven miles, Etna will emit a liquid fire capable of traversing a path of thirty miles. The crater of Vesuvius, moreover, has seldom exceeded half a mile in circumference, while that of Etna is commonly three, and sometimes six, miles.—The best description of this crater, which we have received in our own day, is that given by Spalanzani. According to him, it forms an oval extending from east to west, inclosed by vast fragments of lava and scoriæ; the inner sides being of various declinations, in-

crusted with orange coloured concretions of muriat of ammonia, the sal ammoniac of the shops. The bottom is a plain nearly horizontal, about two-thirds of a mile in circumference, with a large circular aperture, giving vent to a column of white smoke, below which is visible a liquid fiery matter, like metal boiling in a furnace. Such is the height of Etna, that its eruptions rarely attain its summit, but more usually break out at its sides. Near the crater begins the region of perpetual snow and ice; which is followed by a woody domain, consisting of vast forests of oaks, beeches, firs and pines, while the areola of the crater is almost destitute of vegetation. In this middle region appear also chesnut trees of enormous size, one of which, distinguished by the name of *cento cavallo* (troop of horses) measures not less than *two hundred and four feet* in circumference.

Etna is perhaps one of the oldest volcanoes in Europe; and though less minutely described by modern philosophers and travellers than Vesuvius, obtained far more of the attention of the Greek and Roman writers. The fire which is so perpetually burning in its bowels induced the poets to place in this tremendous cavity the forges of the Cyclops, who were placed under the government of Vulcan, and the prison of the giants who rebelled against Jupiter. These fictions progressively grew into popular truths among the vulgar, who regarded Etna, in consequence, as the residence of Vulcan, and the seat of his empire. And hence they erected a temple to him on the mountain, in which, according to Ælian, a perpetual fire was maintained, in the same manner as in the temple of Vesta, this element being an appropriate Vulcanic symbol.

Homer makes mention of Mount Etna, but at the same time takes no notice of its eruptive power; and hence there is a strong presumptive proof that its volcanic properties were unknown at that æra. Thucydides is the earliest historic writer that alludes to these phænomena. He enumerates three eruptions of the mountain towards the conclusion of his third book, one of which he fixes at four hundred and seventy-four years before the birth of our Saviour, a second fifty years later, while to the third he assigns no date whatever. Pindar composed an ode in the 78th Olympiad, about four or five years after the second eruption, and adverted to by Thucydides, in which he describes its violence, and retains the popular fable just alluded to, that Jupiter had buried the giants in its bowels, and that their struggle to get loose was the cause of the fiery com-

motion*. Lucretius has referred to the volcanic powers of Etna in various places. In his sixth book he endeavours more philosophically to accouut for them; and his first describes the island of Sicily so picturesquely, and at the same time pays so elegant a compliment to Empedocles, who was a native of it, that we cannot forbear quoting the passage, which is as follows, v. 717.

Quorum Agragantinus cum primis Empedocles est:
Insula quem triquetris terrarum gessit in oris;
Quam fluitans circum magnis amfractibus æquor,
Ionium glaucis adspargit virus ab undis,
Æoliæ terrarum oras a finibus ejus.
Heic est vasta Charybdis, et heic Ætnea minanter
Murmura, flammarum rursum se contigere iras,
Faucibus eruptos iterum ut vis evomat igneis,
Ad cœlumque ferat flammai fulgura rursum.
Quæ quom magna modis multis miranda videtur
Gentibus humanis regio, visundaque fertur,
Rebus opima bonis, multâ munita virûm vi;
Nihil tamen hoc habuisse viro præclarius in se,
Nec sanctum magis, et mirum, carumque, videtur.
Carmina quin etiam divini pectoris ejus
Vociferantur, et exponunt præclara reperta;
Ut vix humanâ videatur stirpe creatus.

Thus sung EMPEDOCLES, in honest fame,
First of his sect; whom AGRIGENTIUM bore
In cloud-capt SICILY. The sinuous shores,
Th' IONIAN main, with hoarse unwearied wave
Surrounds, and sprinkles, with its briny dew;
And from the fair ÆOLIAN fields divides
With narrow frith that spurns the impetuous surge.
Here vast CHARYBDIS raves; here Ætna rears
His infant thunders, his dread jaws unlocks,
And heaven and earth with fiery ruin threats;
Here many a wonder, many a scene sublime,
As on he journeys, checks the traveller's steps;
And shews, at once, a land in harvests rich,
And rich in sages of illustrious fame.
But nought so wondrous, so illustrious nought,
So fair, so pure, so lovely can it boast,
EMPEDOCLES, as thou! whose song divine,
By all rehears'd, so clears each mystic lore,
That scarce mankind believ'd thee born of man. GOOD.

* Pyth. Od. I.

No country, indeed, has a juster right to boast of the men of learning it has produced than ancient Sicily. In proof of which it may be sufficient to add to the name of Empedocles, those of Æschylus, Diodorus Siculus, Gorgias, Euclid, Archimedes, Epicharmus, Theocritus.—*Editor*.

SECTION II.

Chronological Account of the several Fires of Mount Etna.

To pass by what is related by Berosus, Orpheus, and other less credible authors, about the eruptions of this mountain, both at the time of the ingress of the Ionian colonies into Sicily, and that of the Argonauts (which latter was in the twelfth age before the Christian account;) we shall first take notice of that which happened at the time of the expedition of Æneas,* who being terrified by the fire of this then burning mountain, left that island; whereof Virgil, l. 3, Æneid, gives this notable description—Æneid iii.

Ignarique viæ, Cyclopum allabimur oris.
Portus ab accessu ventorum immotus et ingens,
Ipse sed horrificis juxta tonat Ætna ruinis,
Interdumque etiam prorumpit ad æthera nubem
Turbine fumantem piceo et candente favillâ.
Attollitque globos flammarum, et sidera lambit.
Interdum scopulos, avulsaque viscera montis
Erigit eructans, liquefactaque saxa sub auras
Cum gemitu glomerat, fundoque exæstuat imo.

The wind now sinking with the lamp of day,
Spent with her toils, and dubious of the way;
We reach the dire Cyclopean shore, that forms
An ample port, impervious to the storms.
But Etna roars with dreadful ruins nigh,
Now hurls a cloud of bursting cinders high,
Involv'd in smoky whirlwinds to the sky;
With loud displosion, to the starry frame
Shoots fiery globes, and furious floods of flame;
Now from her bellowing caverns burst away
Vast piles of melted rocks in open day;
Her shatter'd entrails wide the mountain throws,
And deep as hell her burning center glows. PITT.

After this we find in Thucydides, that in the 76th olympiad,

* As we have no other authority for the eruption here referred to than that of the Æneid, there can be little doubt that the poet invented it to suit his purpose.—*Editor.*

which is about 476 years before Christ, there was another fire, and about fifty years after, another.

Then, in the time of the Roman consuls, there happened four eruptions of Etna, recorded by Diodorus Siculus and Polybius.

The next was in the time of Julius Cæsar, related by the said Diodorus to have been so fierce, that the sea about Lipara (an island near Sicily) by its fervent heat burnt the ships, and killed all fishes thereabout.

Another we read of in the reign of Caligula, about forty years after Christ, which was so dreadful, that it made that Emperor, who was then in Sicily, to fly for it.

About the martyrdom of the Romish St. Agatha, it burned again very fiercely; though, some say, that by virtue of her intercession, it was stayed from reaching Catania.

Again it burned A. C. 812, in the reign of Charles M.

Then from the year 1160 to 1669, all Sicily was shaken with many terrible earthquakes, and the eruptions of the same mountain destroyed a vast tract of inhabited land round about it, and reached as far as Catania; the cathedral of which it destroyed, and the religious men residing in it.

Again in the year 1264, there happened another terrible fire about the time of the death of Charles, king of Sicily and Arragon.

A. 1329 until 1333 there was another. A. 140 another.

A. 1414 another, which lasted till 1447.

A. 1536 another, which lasted a year.

A. 1633 another, continuing several years.

A. 1650, it burnt on the north-east side, and vomited so much fire, that by the fiery torrents, caused thereby, great devastation was made, as Kircher relates in his *Mundus Subterraneus*: whose assistance we have also made use of in the foregoing chronology, together with that of Philotheus.

The same author, having been in Sicily himself, observed, that the people of Catania, digging for pumice stones, do find at the depth of one hundred palms (which is about sixty-eight feet) streets paved with marble, and many footsteps of antiquity; an argument, that towns have stood there in former ages, which may have been overwhelmed by the matter cast out of this mountain. They have also found several bridges of pumice stones, doubtless made by the flux of the fiery torrents, the earth being very much raised since.

Now whether these eruptions are caused by actual subterraneous fires, lighting upon combustible matter; or by fire struck out of

falling and breaking stones, whose sparks meet with nitro-sulphureous or other inflammable subtances heaped together in the bowels of the earth, and by the expansive violence of the fire forced to take more room, and so bursting out with the impetuosity we see; may not be unworthy of a philosopher's speculation.

[*Phil. Trans.* 1668.]

SECTION III.

Eruption of Etna in 1669; *as communicated by several inquisitive English merchants at that time resident in Sicily.*

TOUCHING the fore-runners of this fire, there was, for the space of eighteen days, before it broke out, a very thick dark sky in those parts, with thunder and lightning, and frequent concussions of the earth, which the people make terrible reports of, though I never saw nor heard of any buildings cast down thereby, save a small town or village, called Nicolosi; about half a mile distant from the New Mouth, and some such other slight buildings among those towns, that were after over run by the fire. Besides, it was observed that the old top or mouth of Etna did, for two or three months before, rage more than usual; the like of which did Volcan and Stromboli, two burning mountains to the westward. And the top of Etna must about the same time have sunk down into its old vorago or hole, in that 'tis agreed by all, that had seen this mountain before, that it was very much lowered. Other fore-runners of this fire I have not heard nor met with.

It first broke out on the eleventh of March, 1669, about two hours before night, and that on the south-east side or skirt of the mountain, about twenty miles beneath the Old Mouth; and ten miles from Catania. At first it was reported to advance three miles in twenty-four hours; but at our being there (viz. April 5,) when we were come within a short mile of Catania, it scarce moved after the rate of a furlong a day; and after this degree of progress it continued for fifteen or twenty days after, passing under the walls of Catania a good way into the sea; but about the latter end of this month, and the beginning of May (whether it was that the sea could not receive this matter fast enough, or rather that the mouth above did cast forth a larger quantity) it bent all its force against the city; and having wrought itself up even with the walls thereof, over it passed in divers places; but its chief fury fell upon a very stately

convent, which was that of the Benedictines, having large gardens and other ground betwixt them and the wall: which when it had filled up, it fell with all its force on the convent, where it met with strong resistance, which made it swell (as usually it did where it met with any obstruction) almost as high, as the higher shops in the old London exchange, this convent being built much after that fashion, though considerably bigger. Some parts of this wall were driven in, whole and entire, almost a foot, as appeared by the rising of the tiles in the midst of the floor, and bending of the iron-bars that went cross above And 'tis certain, had this torrent fallen in some other part of the town, it would have made great havoc amongst their ordinary buildings, but here its fury ceased the fourth of May, running hence forward in little channels or streams, and that chiefly into the sea. It had overwhelmed in the upland country some fourteen towns and villages, whereof some were of good note, containing three or four thousand inhabitants, and stood in a very fruitful and pleasant country, where the fire had never made any devastation before; but now there is not so much as any sign where such towns have stood; only the church and steeple of one of them; which stood alone upon a high ground, does still appear.

As to the matter which thus ran, it was nothing else but divers kinds of metals and minerals, rendered liquid by the fierceness of the fire in the bowels of the earth, boiling up and gushing forth, like the water doth at the head of some great river; and having run in a full body for a good stone's cast or more, the extremities thereof began to crust and curdle, becoming, when cold, those hard porous stones, which the people call Sciarri, having the nearest resemblance to huge cakes of sea-coal, full of a fierce fire. These came rolling and rumbling over one another, and where they met with a bank, would fill up and swell over, by their weight bearing down any common building, and burning up what was combustible. The chief motion of this matter was forward, but it was also dilating itself, as a flood of water would do on even ground, thrusting out several arms, or tongues, as they call them.

About two or three of the clock in the night, we mounted an high tower in Catania, whence we had a full view of the mouth; which was a very terrible sight, viz. to see so great a mass or body of mere fire. Next morning we would have gone up to the mouth

itself, but durst not come nearer than a furlong off, for fear of being overwhelmed by a sudden turn of the wind, which carried up into the air some of that vast pillar of ashes, which to our apprehension exceeded twice the bigness of Paul's steeple in London, and went up in a straight body to a far greater height that that; the whole air being thereabout all covered with the lightest of those ashes blown off from the top of this pillar: And from the first breaking forth of the fire until its fury ceased (being fifty-four days) neither sun nor star were seen in all that part.

From the outside of this pillar fell off great quantity of stones, but none very big, neither could we discern any fire in them, nor come to see, where that fiery stuff broke out, there being a great bank or hill of ashes betwixt it and us.

At the mouth whence issued the fire, or ashes, or both, was a continual noise, like the beating of great waves of the sea against rocks, or like thunder afar off, which sometimes I have heard here in Messina, though situated at the foot of high hills, and sixty miles off. It hath also been heard one hundred miles northward of this place, in Calabria, (as I have been credibly informed) whither the ashes have also been carried: and some of our seamen have also reported, that their decks were covered therewith at Zante, though its likely not very thick.

Of those burnt stones or sciarri, I have some by me of divers qualities, and shall procure what more I can, to be sent by the first passage.

About the middle of May we made another journey thither, where we found the face of things much altered, the city of Catania being three quarters of it compassed round with these sciarri, as high as the top of the walls; and in many places it had broke over. The first night of our arrival a new stream or gutter of fire broke forth among some sciarri, which we were walking upon an hour or two before, and they were as high as to be even with the top of the wall. It poured itself down into the city in a small gutter of about three foot broad, and nine foot long of mere fire, the extremities still falling off into those sciarri; but this stream was extinct by the next morning, though it had filled up a great void place with its sciarri. The next night was another much bigger channel discovered, pouring itself over another part of the wall into the castle,

ditch, which continued (as we were informed) some days after our departure. Divers of these small rivulets did run at the same time into the sea, and it does so still at this very day, though faintly.

It was observed, that those streams of fire never grew broader nor visibly longer, nor moved out of the place they were seen in; which put us a little more to examine their working, and we did conclude, that not only then, but in the fury also of its running, it made itself certain crusted gutters to run in, to keep itself, as it were from the air, which by degrees did cool and fix it, as more plainly appeared above at the mouth, where, the first time of our going thither, we found the sciarri generally thus cooled and fixed. And hence also it might proceed, that these live sciarri, meeting with any bank or high ground, would puff and swell up, till they had overcome it; so that in many places, especially under the walls of Catania, were vallies of those sciarri, and the fire never broke forth, or discovered itself in those streams, until it had gained its height; for those rivulets ever went declining.

Having spent a couple of days about Catania, we again went up to the mouth, where now without any danger of fire or ashes we could take a free view both of the old and new channel of the fire, and of that great mountain of ashes cast up. That, which we guessed to be the old bed or channel, was a three-cornered plot of about two acres, with a crust of sciarri at the bottom, and upon that a small crust or surface of brimstone. It was hedged in on each side with a great bank or hill of ashes, and behind and at the upper end rose up that huge mountain of the same matter. Between those two banks the fire seems to have had its passage. At the upper end in the nook upon a little hillock of crusted sciarri was an hole about ten feet wide, whence 'tis probable the fire issued; and it might have had several other such holes, since either crusted over or covered with ashes. At the bottom of this hole the fire was seen to flow along, and below it was a channel of fire, beneath that surface of sciarri, which being cleft atop for some space, we had an easy and leisureable view of the metal flowing along, whose superficies might be a yard broad, though possibly it carried a greater breadth underneath, the gutter going sloping. What depth it had, we could not guess: it was impenetrable by iron hooks, and other instruments we had. We were very desirous to have got some of this matter at the spring head, but we could penetrate no more into it, than

with one's finger into the palm of the hand. 'Tis likely that some running may have been more yielding than we found this. From this channel, but especially from that hole above it, issued great store of a strong sulphureous smoke, wherewith some of our companions were at first almost stifled through inadvertency. About once in a quarter of an hour there would rise a pillar of smoke or ashes, but nothing comparable to the former; which seemed to come from the middle top of that new-made mountain. I confess, it was an omission in us, not to go up to this mountain, being so near; but because it was troublesome, and not without danger, the rest of the company being satisfied with what they had already seen, would not stay to see any more.

At this our last being in Catania we found the people busy in barricading the ends of some streets and passages, where they thought the fire might break in; and this they did by pulling down the old houses thereabout, and laying up the loose stones in manner of a wall, which they said would resist the fire as not being mixed with lime; though it was the great weight and force of that fiery matter in pressing forward, and not its burning, that overthrew the buildings, as plainly appeared in the convent of the Benedictines, and in the town-walls, where the great deluge of fire did pour itself; it not breaking into the city, but pouring itself over the walls, as hath been said.

Unto this very time 'tis said to have run a mile into the sea, and as much in front, though it was much less when we were there. The shore goes gently declining, having at the extremity of the sciarri about five fathoms, and about half as much they are above water.

The superficies of the water for twenty foot or more of those rivulets of fire, was hotter than to endure one's hand in it, though deeper it was more temperate, and those live sciarri still retained their fire under water, as we saw when the surges of the sea retreated back in their ordinary reverberations.

The general face of these sciarri is in some respect not much unlike, from the beginning to the end, to the river of Thames in a great frost, at the top of the ice above bridge, I mean, lying after such a rugged manner in great flakes: but its colour is quite different, being most of a dark dusky blue, and some stones or rocks of a vast bigness, close and solid.

But notwithstanding their ruggedness, and store of fire which we could see glowing in the clefts and cavities, we made a shift to ramble over a good part of them; as it is said also that people would do the same in its greatest violence of burning. For as those live sciarri, and those rivers of fire themselves were so tough and impenetrable as to bear any weight, so the superficies of the sciarri might be touched and handled, the fire being inward, and not to be discerned but near hand, especially in the day time: and it was somewhat a strange sight to see so great a river come so tamely forward; for, as it approached unto any house, they not only at good leisure removed their goods, but the very tiles and beams, and what else was moveable.

'Tis observable that none of those that went to see it, when there was little else to be seen but the cold sciarri, but declared to have found it a much other thing than they imagined, though related to them *viva voce* by those who had formerly been there.

I shall add, that the whole country from the very walls of Catania to twenty miles on this side is full of old sciarri, which former eruptions have cast forth, though the people remember none so big as this last, or that burst out so low. This country is notwithstanding well cultivated and inhabited; for length of time hath either mollified much of those old sciarri, or new mould or ashes have overgrown them, though there still remains much country which it may be will never be made serviceable.

What is the perpendicular height of this mountain I cannot learn. It cannot perhaps be rightly taken, being so subject to alter its height and shape. But it is a very goodly mountain to look upon, as one passes by sea to the eastward, standing alone by itself, rising from the very shore; and at shortest passage is reckoned twenty miles up to the top, though from Catania it hath thirty miles as before. [*Phil. Trans.* 1669.]

SECTION IV.

Changes, present State, and picturesque Scenery of Etna.

THREE hours before day, I, with my companions, left the Grotta delle Capre, which had afforded us a welcome asylum, though our bed was not of the softest, as it consisted only of a few oak leaves scattered over the floor of lava. I continued my journey towards

the summit of Etna; and the clearness of the sky induced me to hope that it would continue the same during the approaching day; that I might enjoy the extensive and sublime prospect from the top of this lofty mountain, which is usually involved in clouds. I soon left the middle region, and entered the upper one, which is entirely destitute of vegetation, except a few bushes very thinly scattered. The light of several torches which were carried before us enabled me to observe the nature of the ground over which we passed, and to ascertain, from such experiments as I was able to make, that our road lay over lavas either perfectly the same with, or analogous to, those in which the Grotta delle Capre is hollowed.

We had arrived at within about four miles of the borders of the great crater, when the dawn of day began to disperse the darkness of night. Faint gleams of a whitish light were succeeded by the ruddy hues of Aurora; and soon after the sun rose above the horizon, turbid at first and dimmed by mists, but his rays insensibly became more clear and resplendent. These gradations of the rising day are no where to be viewed with such precision and delight, as from the lofty height we had reached, which was not far from the most elevated point of Etna. Here, likewise, I began to perceive the effects of the eruption of Etna which took place in July 1787, and which has been so accurately described by the Chevalier Gioeni*. These were visible in a coating of black scoriæ, at first thin, but which became gradually thicker as I approached the summit of the mountain, till it composed a stratum of several palms in thickness. Over these scoriæ I was obliged to proceed, not without considerable difficulty and fatigue, as my leg at every step sank deep into it. The figure of these scoriæ, the smallest of which are about a line or somewhat less in diameter, is very irregular. Externally they have the appearance of scoriæ of iron; and, when broken, are found full of small cavities, which are almost all spherical, or nearly of that figure. They are, therefore, light and friable; two qualities which are almost always inseparable from scoriæ. This great number of cavities is an evident proof of the quantity and vigorous action of the elastic fluids, which in this eruption, imprisoned in the liquid

* His account of this eruption was printed at Catania in 1787. There is likewise a French translation at the end of the *Catalogue Raisonné* of M. Dolomieu.

matter within the crater, dilated it on every side, seeking to extricate themselves; and forced it, in scoriaceons particles, to various heights and distances, according to the respective weights of those particles. The most attentive eye cannot discover in them the smallest shoerl; either because these stones have been perfectly fused, and with the lava passed into one homogeneous consistence; or because they never existed in it. Some linear feltspars are however found, which by their splendour, semi-transparency, and solidity, shew that they have suffered no injury from the fire. When these scoriæ are pulverized, they become extremely black; but retain the dryness and scabrous contexture which they had when entire. They abound in iron, and in consequence the dust produced by pulverizing them copiously adheres to the point of a magnetized knife; and a small piece of these scoriæ will put the magnetic needle in motion at the distance of two lines.

In the midst of this immense quantity of scoriæ, I, in several places, met with some substances of a spherical figure, which, like the lava, were at first small, but increased in size as I approached the summit of the mountain. These were originally particles of lava ejected from the crater in the eruption before mentioned, which assumed a spherical figure when they were congealed by the coldness of the air. On examining them, I found them in their qualities perfectly to resemble the scoriæ, and to possess the same magnetism.

Only two miles and a half remained of our journey, when the great laboratory of nature, inclosed within the abysses of Etna, began its astonishing operations. Two white columns of smoke arose from its summit; one, which was the smallest, towards the north-east side of the mountain; and the other, towards the north-west. A light wind blowing from the east, they both made a curve towards the west, gradually dilating, until they disappeared in the wide expanse of air. Several streams of smoke, which arose lower down, towards the west, followed the two columns. These appearances could not but tend to inspire me with new ardour to prosecute my journey, that I might discover and admire the secrets of this stupendous volcano. The sun, likewise, shining in all his splendour, seemed to promise that this day should crown my wishes. But experience taught me that two miles and a half I had yet to go presented many more obstacles than I could have imagined, and that

nothing but the resolution I had formed to complete my design at every hazard could have enabled me to surmount them.

Having proceeded about a hundred paces further, I met with a torrent of lava, which I was obliged to cross, to arrive at the smoking summit. My guides informed me that this lava had issued from the mountain in October 1787; and as the account of the Chevalier Gioeni, which I have above cited, only mentions the eruption of the month of July of the same year, I shall here give a brief description of it; as it does not seem hitherto to have been described.

This very recent lava extends three miles in length; its breadth is various, in some places being about a quarter of a mile, in others one-third, and in others still more. Its height, or rather depth, is different in different parts; the greatest being, as far as I was able to observe, about eighteen feet, and the least six. Its course is down the west side of the mountain; and, like the other lava which flowed in the July of 1787, it issued immediately from the great crater of Etna. The whole number of the eruptions of this mountain of which we have any record, before and after the Christian era, is thirty-one; and ten only, as we are informed by Gioeni, including that of which he has given an account, have issued immediately from the highest crater. That which I observed may be the eleventh, unless it should rather be considered as the same with that described by the Sicilian naturalist; since the interval between August and October is a very short intermission of rest for a volcano. The cause of the rarity of the eruptions which issue immediately from the crater, compared with those which disgorge from the sides, seems easily to be assigned. The centre of this volcano is probably at a great depth, and perhaps on a level with the sea. It is therefore much more easy for the matter liquified by the fire, put in effervescence by the elastic fluids, and impelled on every side from the centre to the circumference, to force its way through one of the sides of the mountain where it finds least resistance, and there form a current, than to be thrown up, notwithstanding the resistance of gravity, from the bottom to so great a height as the highest crater of Etna. It is evident, therefore, that the effervescence in the eruptions of the months of July and October 1787 was extremely violent. The torrent of the month of October is every where covered with scoriæ, which resemble those ejected in the month of

July in their black colour, but differ from them in the great adhesion they have to the lava, in their exterior vitreous appearance, their greater weight, and their hardness, which is so great that they give sparks with steel almost as plentifully as flints. These differences, however, are to be attributed only to accidental combinations of the same substance; the constituent principles of the scoriæ of this lava not being different from those of the detached scoriæ mentioned above. Both, likewise, contain the same feltspar lamellæ.

This new current was, however, extremely difficult, and even dangerous, in the passage. In some places the scoriæ projected in prominent angles and points, and in others sunk in hollows, or steep declivities; in some, from their fragility and smoothness, they resembled thin plates of ice, and in others they presented vertical and sharp projections. In addition to these difficulties, my guides informed me I should have to pass three places where the lava was still red-hot, though it was now eleven months since it had ceased to flow. These obstacles, however, could not overcome my resolution to surmount them, and I then experienced, as I have frequently done at other times, how much may be effected in difficulties and dangers like these, by mere physical courage, by the assistance of which we may proceed along the edge of a precipice in safety; while the adventurer who suffers himself to be surprised by a panic fear will be induced cowardly to desist from the enterprise he might have completed. In several places, it is true, the scoriæ broke under my feet; and in others I slipped, and had nearly fallen into cavities from which I should have been with difficulty extricated. One of the three places pointed out by the guides had, likewise from its extreme heat, proved highly disagreeable; yet, at length, I surmounted all these obstacles and reached the opposite side, not without making several cursory observations on the places whence those heats originated. Two large clefts, or apertures, in different places appeared in the lava, which there, notwithstanding the clearness of the day, had an obscure redness; and on applying the end of the staff which I used as a support in this difficult journey, to one of these, it presently smoked, and, immediately after, took fire. It was therefore indubitable, that this heap of ejected lava still contained within it the active remains of

fire, which were more manifest there, than in other places, because those matters were there collected in greater quantities.

I had yet to encounter other obstacles. I had to pass that tract which may properly be called the cone of Etna, and which, in a right line, is about a mile, or somewhat more in length. This was extremely steep, and not less rugged, from the accumulated scoriæ which had been heaped upon it in the last eruption, the pieces of which were neither connected together, nor attached to the ground; so that, frequently, when I stepped upon one of them, before I could advance my other foot, it gave way, and, forcing other pieces before it down the steep declivity, carried me with it, compelling me to make many steps backwards instead of one forwards. To add to this inconvenience, the larger pieces of scoriæ above that on which I had stepped, being deprived of the support of those contiguous to them, came rolling down upon me, not without danger of violently bruising my feet, or breaking my legs. After several ineffectual attempts to proceed, I found the only method to avoid this inconvenience and continue my journey, was to step only on those larger pieces of scoriæ which, on account of their weight, remained firm: but the length of the way was thus more than doubled, by the circuitous windings it was necessary to make to find such pieces of scoriæ as from their large size were capable of affording a stable support. I employed three hours in passing, or rather dragging myself to the top of the mountain, partly from being unable to proceed in a right line, and partly from the steepness of the declivity, which obliged me to climb with my hands and feet, sweating and breathless, and under the necessity of stopping at intervals to rest, and recover my strength. How much did I then envy the good fortune of those who had visited Etna before the eruption of 1787, when, as my guides had assured me, the journey was far less difficult and laborious!

I was not more than a hundred and fifty paces distant from the vertex of the cone, and already beheld close to me, in all their majesty, the two columns of smoke. Anxious to reach the borders of the stupendous gulph, I summoned the little strength I had remaining, to make a last effort, when an unforeseen obstacle, for a moment, cruelly retarded the completion of my ardent wishes. The volcanic craters, which are still burning more or less, are

usually surrounded with hot sulphureous acid streams, which issue from their sides, and rise in the air. From these the summit of Etna is not exempt; but the largest of them rose to the west, and I was on the south-east side. Here, likewise, four or five streams of smoke arose, from a part somewhat lower; and through these it was necessary to pass; since on one side was a dreadful precipice, and on the other so steep a declivity that I and my companion, from weakness and fatigue, were unable to ascend it; and it was with the utmost difficulty that our two guides made their way up it, notwithstanding they were so much accustomed to such laborious expeditions. We continued our journey, therefore, through the midst of the vapours; but though we ran as fast as the ground and our strength would permit, the sulphureous steams with which they were loaded were extremely offensive, and prejudicial to respiration; and affected me, in particular, so much, that for some moments I was deprived of sense; and found, by experience, how dangerous an undertaking it is to visit volcanic regions invested by such vapours.

Having passed this place, and recovered by degrees my former presence of mind; in less than an hour I arrived at the utmost summit of Etna, and began to discover the edges of the crater; when our guides, who had preceded me at some distance, turned back, and, hastening towards me, exclaimed in a kind of transport, that I never could have arrived at a more proper time to discover and observe the internal part of this stupendous volcano. The reader will easily conceive, without my attempting to describe it, how great a pleasure I felt at finding my labours and fatigue at length crowned with such complete success. This pleasure was exalted to a kind of rapture, when I had completely reached the spot, and perceived that I might, without danger, contemplate this amazing spectacle. I sat down near the edge of the crater, and remained there two hours, to recover my strength after the fatigues I had undergone in my journey. I viewed with astonishment the configuration of the borders, the internal sides, the form of the immense cavern, its bottom, an aperture which appeared in it, the melted matter which boiled within, and the smoke which ascended from it. The whole of this stupendous scene was distinctly displayed before me; and I shall now proceed to give some description of it, though it will only

now appeared so calm and still, would long remain in the same state; but that it was possible, from circumstances difficult to foresee, that it might be thrown up on a sudden, and punish our imprudent curiosity by burying us beneath the fiery ruin; in support of which suggestion they produced several instances of sudden and most unexpected eruptions.

We have seen above, that there were two columns of smoke arising from tna. It is to be remarked that, besides that point of Mount Etna on which I stood, there is another to the north, a quarter of a mile higher; and which renders the summit of Etna properly bifurcated. Within the first prominence is sunk the crater I have described; and on the side of the other is the second, from which ascends a lesser column of smoke. The second crater is smaller by about the one-half than that I have already described; and the one is separated from the other only by a partition of scoriæ and accumulated lava, which lies in the direction of from east to west. I made my observations on this second crater from a small distance; but it was impossible to advance to it, on account of the numerous and thick streams of smoke by which it was surrounded. This, however, was no great disappointment, after having seen and examined the principal crater, which is that whence several currents of lava had issued in 1787. I ought, certainly, to consider myself as extremely fortunate, in being able to gratify my curiosity with so near and distinct a view of the objects I have described; as the guides assured me, that, among all the times when they had conducted strangers to the summit of Etna, this was the only one in which they had a clear and undisturbed view of the internal parts of that immense gulph. After my return to Catania, the Chevalier Gioeni likewise declared to me that, in all his different excursions to that mountain, he had never had a good fortune similar to mine; and that, a month before my arrival, he had made a journey to Etna, with the Chevalier Dangios, furnished with the necessary instruments to ascertain accurately the height of the mountain; but when they had arrived at the foot of the cone, where they had proposed to begin their operations, they were obliged to return back from the obstacles they met with, which, to say the truth, are commonly neither few nor small.

Etna rises to a prodigious height above the level of the sea, and

its summit is usually covered with snows and ice, and obscured with clouds, except when the latter are low and range along the sides. The winds, likewise, frequently blow with such violence that persons can scarcely keep their feet, not to mention the acute cold which benumbs the limbs. But the most formidable impediments to the progress of the adventurers who attempt this perilous journey, are the streams of sulphureous vapour which rise on the sides, and the thick clouds of sulphureous smoke which burst forth from the mouth of the volcano, even when not in a state of agitation. It seems as if nature had placed these noxious fumes as a guard to Etna, and other fiery mountains, to prevent the approach of curiosity, and secure her mysterious and wondrous labours from discovery. I should, however, justly incur the reproach of being ungrateful, were I not to acknowledge the generous partiality she appeared to manifest towards me. At the time I made my visit, the sky was clear, the mountain free from snows, the temperature of the atmosphere not incommodious, the thermometer standing at seven degrees above the freezing point (forty eight degrees of Fahrenheit), and the wind favouring my design, by driving the smoke of the crater from me, which otherwise would alone have been sufficient to have frustrated all my attempts. The streams of smoke I met with in my way were, indeed, somewhat troublesome, but they might have been much more so; though, had our guides conducted us by another road, as, on my return to Catania, I found they might have done, we should have escaped this inconvenience.

It here will not be improper to compare these observations on the crater of Etna with those of Baron Riedesel, Sir William Hamilton, Mr. Brydone, and Count Borch; as such a comparison will shew the great changes which have taken place in this volcano, within the space of twenty years; that is, from the time when it was visited by Baron Riedesel, in 1767, to that of my journey, in 1788. At the time when that traveller made his observations, the crater was enlarged towards the east, with an aperture which now no longer exists. He has not given the measure of its circuit, nor has he mentioned the interior aspect of the crater; probably because he had not seen it, having been, as I imagine, prevented by the quantity of smoke which, he tells us, continually ascended from it.

It is worthy of notice, however, that at that time there was not at the bottom of the crater the hard flat surface I have described; since the stones thrown into it did not return the smallest sound. Within the gulph itself, was heard a noise similar to that of the waves of the sea when agitated by a tempest, which noise, probably proceeded from the lava within the bowels of the mountain, liquefied and in motion. We may hence conceive how easily a volcano may begin to rage on a sudden, though before apparently in a state of complete tranquillity; for if we suppose a superabundant quantity of elastic substances to have been suddenly developed in the liquid lava of Etna, either at the time when Baron Riedesel visited the crater, or when I observed it in a state of slight commotion within the gulf, it must immediately have swelled in every part, beating violently against the sides of the caverns in which it was imprisoned, thundered among the deep cavities, and, bursting forth through the sides, have poured out a river of fire; or, should its violence have been there resisted, it would have rushed up within the crater, until it overflowed its brink, and deluged the sides of the mountains with its torr. nts.

Sir William Hamilton, on the 26th of October 1769, arrived at the summit of Etna, with great difficulty, on account of the snows he met with in his way, the severity of the atmosphere, the sulphureous vapours, and the violence of the wind. He was unable to view distinctly the lower parts of the crater, being prevented by the great quantity of smoke which issued from it; though, when this smoke was sometimes driven away by the wind, he could discover that the crater was shaped like a funnel, diminishing until it ended in a point; and that this funnel was incrusted over with salt and sulphur. The crater was two miles and a half in circumference.

From the time, therefore, of the journey of Baron Riedesel to that of Sir William Hamilton, the crater must have undergone great changes in its structure; since, if the stones that were thrown into it gave no indications to the ear that they struck against any solid body, it is manifest that there must have been an abyss as well as a funnel; and as the funnel terminated in a point, when it was observed by Sir William Hamilton, it is evident that the flat bottom I have described, and which was about two-thirds of a mile in circuit, did not then exist.

The internal sides of the crater, Sir William tells us, were covered with a crust of salt and sulphur: but he does not specify the nature of the former; and though the presence of the latter is not improbable, he might have been led into a mistake by the yellow colour, and have taken the muriate of ammonia (sal ammoniac) for sulphur, as I did before I had examined it. Sir William has not told us that he made any examination at all; and it is probable that he judged only from the appearance it presented to his eye.

He observes, lastly, that the crater was two miles and a half in circumference; an estimate which may be made to agree with mine by neglecting the partition which separates the greater crater from the less, and considering them both as one. The sum of the two circumferences, according to the estimate I have given, would not then greatly differ from the measure of Sir William Hamilton. Nothing, likewise, can be more probable, than that among the various changes that have happened to Etna, this partition, by which the great crater is divided into two parts, has been produced.

Omitting the observation of Mr. Brydone, that "the tremendous gulf of Etna, so celebrated in all ages, has been looked upon as the terror both of this and another life, that inspires such awe and horror, that it is not surprising that it has been considered as the place of the damned;" and reflections of a similar kind which he has employed; and confining ourselves to what he actually saw on the 29th of May 1770, we learn from him that "the crater was then a circle of about three miles and a half in circumference; that it went shelving down on each side, and formed a regular hollow, like a vast amphitheatre; and that a great mouth opened near the centre*.

From the time of the journey of Sir William Hamilton, therefore, to that of the visit of Brydone, that is to say, within the short space of a year, various changes had happened to this volcano, by the enlargement of its crater, and a spacious aperture formed in its bottom.

Count Borch appears to have wished to exceed the three other travellers in brevity, relative to this subject; since he only tells us

* Brydone's Tour through Sicily and Malta, Vol. I. p. 195, 196.

that he arrived at the mountain on the 16th of December 1776, and that the crater of Etna is formed like a funnel. He adds, however, what is worthy of notice, that the summit of Etna is bifurcated, as I observed it to be: a circumstance not noticed by others, Sir William Hamilton even affirming that the summit of the mountain is single; whence we may conclude that one of these summits has been produced since the time of the journey of Brydone, in 1770.

On comparing the above-cited observations, made within the space of twenty-one years, we may perceive how many changes have taken place in Etna during that interval; and as, within that time, the mountain has suffered only two violent convulsions, in the eruptions of 1781 and 1787, it is evident that, even in the state of apparent inaction, it still internally exerts its force.

To these observations it may, likewise, not be without utility to add those of M. D'Orville. He ascended Etna in 1727, and remarked two craters, one larger than the other. The latter he only mentions, but the former he describes at some length. Its circumference was, perhaps, somewhat more than four miles. From it issued clouds of smoke and reddish flames. These, however, did not prevent his approaching to the edge of the gulf; though, to prevent the danger of falling into it, he and his companions fastened themselves to a rope held by three men. On looking into the crater, they were unable to discern the bottom, on account of the flames and smoke: they only observed that a conical hill, formed of lava, rose in the middle of the crater, the top of which they estimated to be sixty feet below them; and they were able to see, perhaps, about sixty feet lower: where they conjectured the circuit of this hill might be from six hundred to eight hundred feet *.

We have here a remarkable circumstance relative to Etna, as it appeared in the time of M. D'Orville, and not observed by any one of the four travellers above cited—I mean the conical hill within the crater. Every observation, therefore, tends to confirm the inconstancy of the internal configuration and dimensions of this volcano. It is an extinguished forge, which, in proportion to the violence of the fire, to the nature of the fossil matters on which it acts, and of the elastic fluids which urge and set it in motion, produces, destroys,

* Jacobi Philippi D'Orville Sicula.

and re-produces various forms. The usual and natural figure of the summit of a volcanic mountain is that of an inverted concave cone within, and one solid and erect without; and such a configuration, in countries which are no longer in a state of conflagration, is one of the most certain indications of the existence of an ancient volcano. This cone, however, is liable to very great changes; according to the greater or less fury of the volcano, and the quantity and quality of the matters ejected. Its internal part, from more than one cause, is exposed to continual violence and change. The prodigious cavities of the mountain make it almost appear suspended in the air. It may easily, therefore, give way, and fall in; especially on the violent impulse of new matters which endeavour to force a passage through the upper part; in consequence of which the inverted cone, according to circumstances, present the appearance of an aperture, or whirlpool, or a gulf. Should the liquid lava pass through the aperture, and continue there some time, its superficies, by the contact of the cold air, losing its heat gradually, would congeal, and form a crust or solid plane; and should the fluid lava beneath, afterwards, act forcibly on this crust, it might burst it, or make a passage where it found least resistance; in which case the melted lava would occupy that aperture. Should then the crust, instead of ascending in a single body, be forced up in small fragments, these, cooled in the air, would fall down, in immense quantities, within the crater, and, from the effect of the laws of gravity, must accumulate in the figure of a cone. These theoretical conjectures, if they do not perfectly explain, may at least enable us to conceive, the nature of the causes which have produced the difference of appearance observed at different times in the crater of Etna.

It is much to be regretted that we have no history of Etna; which, did we possess it, must greatly contribute to elucidate the theory of volcanoes, and the causes of the various changes which have taken place, at different times, in the summit of this mountain. That such changes have happened, is evident from the few, but valuable, notices concerning Etna, which we find in ancient authors. Of these I shall briefly state two or three which appear to be of most importance.

I shall first produce the authority of Strabo, though he was not himself an ocular witness, but relied on the information of others.

who had visited Etna, and from whom he received the account, "That the summit was a level plain, of about twenty stadia in circumference, surrounded by a brow, or ridge, of the height of a wall; and in the middle of the plain arose a smoky hill, the smoke of which ascended in a direct line, to the height of two hundred feet."

If we consider this description as accurate, the crater of Etna was at that time surrounded by a brow or ridge, which I should explain as the sides or edges; and, in the lower part, was separated by a mount rising in the middle*. The same geographer relates that two men, having ventured to descend upon that plain, were obliged immediately to return, from the violence of the heat.

Solinus tells us that there were two craters from which the vapours issued†.

Cardinal Bembo likewise found two craters on the summit, the one higher than the other, and about as far distant as a stone might be thrown from a sling. The extreme violence of the wind, and the exhaling fumes, prevented him from approaching the upper crater. The lower he found to be formed like an immense pit, and surrounded with a plain of no great extent, which was so hot that he could not bear his hand on it. From its mouth, as from a chimney, continually issued a column of smoke.

Of the other crater, which he could not observe himself, he received a description, at Catania, from a monk, who, he assures us, was a man deserving of credit, and well acquainted with such subjects. He informed him that this crater was situated on the highest part of the summit of Etna; that it was about three miles in circumference; formed like a funnel; and that it had in the middle a spacious cavity. He asserted that he had made a circuit of it, along a kind of narrow ridge; that, from time to time, it threw out stones and burning matters, to a considerable height, roaring, and shaking the ground; but that, in the intervals when it was undisturbed, he had observed it without danger or difficulty.

* This observation agrees with that of D'Orville mentioned above. I find, likewise, that similar mounts have sometimes been thrown up within the crater of Vesuvius. De Bottis *Istoria di varj incendj del Vesuvio*.

† In Etnæ vertice hiatus duo sunt, crateres nominati, per quos eructatus erumpit vapor. Cap. xi.

In the time of Fazello, however, who visited Etna after Cardinal Bembo, there were no longer two craters, but only one; the circumference of which as he informs us, was four miles. It had the usual form of the funnel, emitted fire and thick smoke, but, at intervals, was calm, and might be approached; at which times a subterraneous noise was heard, and a sound like that of the boiling of an immense caldron on a vast fire. These observations were made by him in 1541, and 1554; in both which years the crater appears to have been single *.

These few citations appear to me sufficient to shew what changes have taken place in the summit of Etna, relative to the number, the form, and the size of its craters, according to the different effects of its conflagrations at different times. But there is likewise another alteration which should not be passed unnoticed, described by two writers who themselves observed it, Fazello and Borelli; I mean the falling-in and absorption of the extreme summit of Etna within its crater. The former of the abovementioned authors relates that, in his time, there arose, in the mouth of the crater, a little hill, isolated on every side, which formed the vertex of the mountain; and which, in a terrible eruption, fell into, and was buried in, the gulf, thus enlarging the crater, and diminishing the height of the mountain. This hill itself had been produced by a former eruption in 1444*.

In like manner, Borelli informs us that, in the conflagration of 1669, the summit of Etna, which rose like a tower to a great height above the part which is level, was swallowed up in the deep gulf †.

I have already said, that when I visited Etna its summit was divided into two points, or little mountains, one of which rose a quarter of a mile above the other. I should not be surprised were I to hear that, in some new and fierce eruption, the highest of these had fallen in, and the two craters become one of much larger dimensions. We know that the summit of Vesuvius has sometmies fallen down in the same manner; nor does it appear difficult to assign the cause. It seems to admit of no doubt that the highest parts of Etna, and other mountains which vomit fire from their summits, have their

* Fazel. Sic. † Ubi sup. ‡ Ubi sup.

foundations on the sides of the crater, which extend to an immense depth. In any violent earthquake, therefore, or impetuous shock of the lava endeavouring to force a passage, it may easily be imagined that those foundations must be torn up and broken away, and the summit of the volcano fall and be lost in the gulf.

These dilapidations have not, however, from time immemorial, produced any sensible diminution of the height of the summit of Etna; since the losses occasioned by some eruptions are repaired by others which follow. This may be inferred from a phenomenon usually inseparable from the summit of Etna, though, by a rare accident, not observable at the time of my journey; I mean the ice and snow with which it is covered. Had any considerable decrease of the height of the mountain taken place, in consequence of the summit repeatedly falling in in former ages, the ice and snow would not certainly, in a climate so mild, have continued to envelop the top of the mountain, as they now do, even during the greatest heats of summer. But this continual residence of the snow and ice on Etna has been celebrated by all antiquity; for near observation was not necessary to ascertain this phenomenon, since it is distinctly apparent at the distance of a hundred miles. "Adscendit ea regio (says Fazello, speaking of the Upper Region of Etna) passuum millia fere xii.; quæ per hyemem tota nivibus obsita extremisque frigoribus riget: per æstatem quoque nulla sui parte nec canitie nec gelu caret: quod equidem admiratione dignum est; cum vertex incendia prope sempiterna jugi flammarum eructatione inter nives ipsas pariat, enutriat, ac continuet."—"This region extends nearly twelve miles; and, even in summer, is almost perpetually covered with snow, and extremely cold; which is the more wonderful as the summit continually produces, nourishes, and pours forth flames, amid the ice and snow with which it is enveloped."

Solinus and Silius Italicus give the same description. The former says—"Mirum est quod in illa ferventis naturæ pervicacia mixtas ignibus (Etna) nives profert: et licet vastis exundet incendiis, aprica canitie perpetuo brumalem detinet faciem *."—"Etna, in a wonderful manner, exhibits snows mixed with fires; and retains every appearance of the severest winter amid her vast conflagrations."

* Cap. xi.

Silius Italicus has the following lines:

Summo cana jugo cohibet (mirabile dictu)
Vicinam flammis glaciem, æternoque rigore
Ardentes horrent scopuli; stat vertice celsi
Collis hyems, calidaque nivem tegit atra favilla *.

Where burning Etna, towering, threats the skies,
'Mid flames and ice the lofty rocks arise;
The fire amid eternal winter glows,
And the warm ashes hide the hoary snows.

And since I have quoted one poet, I will cite two others; Claudian and Pindar; as it is sufficiently evident that poetry here must express truth and not fiction.

Sed quamvis nimio fervens exuberet æstu,
Scit nivibus servare fidem: pariterque favillis
Durescit glacies, tanti secura vaporis,
Arcano defensa gelu, fumoque fideli
Lambit contiguas innoxia flamma pruinas †.

Amid the fires accumulates the snow,
And frost remains where burning ashes glow;
O'er ice eternal sweep th' inactive flames,
And winter, spite of fire, the region claims.

Thus the Latin poet; but the Greek has given us a picture of Etna much more highly coloured, representing it not only as the eternal abode of snows, but as the column of heaven, to express its astonishing height.

Κιων δ' ὠρανια
Νιφοεσσ' Αιτνα πανετες
Χιονος ὀξειας τιθηνα ‡.

—Snowy Etna, nurse of endless frost,
The mighty prop of heaven.

It is to be remarked that Pindar lived five hundred years before the Christian æra.

I now return from this digression, which, though not indeed very short, appears to me perfectly appropriate to the subject; and pro-

* Lib. xiv. † Claud. de Rapt. Pros. ‡ Pind. Pyth. Od. I.

ceed to resume my narrative. I shall first speak briefly of a phenomenon relative to the smoke which arises from the crater of Etna, and which was seen differently by Mr. Brydone, Count Borch, and myself. Mr. Brydone tells us that, "from many places of the crater issue volumes of sulphureous smoke, which being much heavier than the circumambient air, instead of rising in it, as smoke generally does, immediately on its getting out of the crater, rolls down the side of the mountain, like a torrent, till coming to that part of the atmosphere of the same specific gravity with itself, it shoots off horizontally, and forms a large track in the air according to the direction of the wind."

On the contrary, the smoke when seen by Count Borch, at the intervals when the air was calm, arose perpendicularly to a great height, and afterwards fell, like white fleeces, on the top of the mountain. I shall not presume to doubt these two facts, though I observed neither of them. The two columns of smoke which I saw, though bent somewhat from the perpendicular by the wind, ascended with the usual promptitude of ordinary smoke (a certain proof that it was considerably lighter than the ambient air), and, when at a great height, became extremely rarefied and dispersed. This difference in the appearance of the smoke, as observed by the two authors before mentioned and myself, may arise not only from the gravity of the air on Etna being different at different times, but also from the diversity of the smoke, which may be sometimes lighter and sometimes heavier than the air that surrounds it; differing in its nature according to the quality of the substances from which it is produced. Such a variation in its specific gravity must induce us to conclude that the bodies which burn within the crater are specifically different.

The effects of the air at the summit of Etna, as experienced by myself and some of the travellers I have before cited, were likewise different. Sir William Hamilton tells us, that the thinness of that fluid occasioned a difficulty of respiration; and Count Borch appears to have experienced a still greater inconvenience of that kind, since he says—"The rarity of the air on this mountain is extremely sensible, and almost renders that fluid unfit for respiration." On the contrary, Baron Riedesel felt no such effect, as far at least as we can judge from his own words. "I did not perceive, as several travellers have asserted, that the air here is so thin and rarefied as to

prevent, or or at least greatly incommode, respiration." Mr. Brydone has said nothing on the subject, and his silence may induce us to conclude that he experienced no difficulty.

I, my servant, and two guides, suffered no inconvenience from the air. The exertions we had made, indeed, in climbing up the craggy steep declivities which surround the crater, had produced a shortness of breathing; but when we had reached the summit, and recovered from our weariness by rest, we felt no kind of inconvenience, either while sitting, or when, incited by curiosity, we went round and examined different parts of the edges of the crater. The same is affirmed by Borelli: "Æquè bene respiratio in cacumine Ætnæ absolvitur, ac in locis subjectis campestribus."—"Respiration is performed with the same ease on the top of Etna, as in the country below."

Several writers have treated of the difficulty of respiration experienced by those who travel over high mountains, and other inconveniencies to which they are exposed; but none, in my opinion, more judiciously than M. Saussure, in his Travels among the Alps. The observations he has made appear to me to explain the cause of these different accounts relative to the effect of the air on the top of Etna. When the height above the level of the sea was 2450 poles, or nearly such, which he found to be that of Mount Blanc, every individual felt more or less inconvenience from the rarefaction of the air, as happened to himself and nineteen persons who accompanied him, when, in August 1787, he ascended that mountain. But when the elevation was much less, as for example 1900 poles, some of these persons felt no difficulty, among whom was this naturalist; though he confesses that he began to experience inconvenience as he ascended higher. We have not indeed any certain observations relative to the exact height of Etna, as is sufficiently proved by the different estimates given by different naturalists. Signor Dangois, however, astronomer at Malta, in the year 1787, measured the height of this mountain by a geometrical method, and the public anxiously expects the results, which will satisfactorily solve this important problem. In the mean time, from comparing the measures hitherto assigned, the elevation of Etna above the level of the sea is probably somewhat less than 1900 poles. Hence we understand why respiration in many persons is not incommoded, while the contrary happens to others, according to the different strength and habit of body of different individuals.

After having for two hours indulged my eyes with a view of the interior of the crater, that is, in the contemplation of a spectacle which, in its kind, and in the present age, is without a parallel in the world; I turned them to another scene, which is likewise unequalled for the multiplicity, the beauty and the variety of objects it presents. In fact, there is perhaps no elevated region on the whole globe which offers, at one view, so ample an extent of sea and land as the summit of Etna. The first of the sublime objects which it presents is the immense mass of its own colossal body. When in the country below it, near Catania, we raise our eyes to this sovereign of the mountains, we certainly survey it with admiration, as it rises majestically, and lifts its lofty head above the clouds; and with a kind of geometric glance we estimate its height from the base to the summit; but we only see it in profile. Very different is the appearance it presents, viewed from its towering top, when the whole of its enormous bulk is subjected to the eye. The first part, and that nearest the observer, is the Upper Region, which, from the quantity of snows and ice beneath which it is buried during the greater part of the year, may be called the frigid zone, but which, at that time, was divested of this covering, and only exhibited rough aud craggy cliffs, here piled on each other, and there separate and rising perpendicularly; fearful to view and impossible to ascend. Towards the middle of this zone, an assemblage of fugitive clouds, irradiated by the sun, and all in motion, increased the wild variety of the scene. Lower down, appeared the Middle Region, which from the mildness of its climate, may merit the name of the temperate zone. Its numerous woods, interrupted in various places, seem, like a torn garment, to discover the nudity of the mountain. Here arise a multitude of other mountains, which in any other situation would appear of gigantic size, but are but pigmies compared to Etna. These have all originated from fiery eruptions. Lastly, the eye contemplates, with admiration, the Lower Region, which, from its violent heat, may claim the appellation of the torrid zone; the most extensive of the three, adorned with elegant villas and castles, verdant hills, and flowery fields, and terminated by the extensive coast, where, to the south, stands the beautiful city of Catania, to which the waves of the neighbouring sea serve as a mirror.

But not only do we discover, from this astonishing elevation, the

entire massy body of Mount Etna; but the whole of the island of Sicily, with all its noble cities, lofty hills, extensive plains, and meandering rivers. In the indistinct distance we perceive Malta; but have a clear view of the environs of Messina, and the greater part of Calabria; while Lipari, the fuming Vulcano, the blazing Stromboli, and the other Eolian isles, appear immediately under our feet, and seem as if, on stooping down, we might touch them with the finger.

Another object no less superb and majestic, was the far-stretching surface of the subjacent sea which surrounded me, and led my eye to an immense distance, till it seemed gradually to mingle with the heavens.

Seated in the midst of this theatre of the wonders of nature, I felt an indescribable pleasure from the multiplicity and beauty of the objects I surveyed, and a kind of internal satisfaction and exultation of heart. The sun was advancing to the meridian, unobscured by the smallest cloud, and Reaumur's thermometer stood in the tenth degree from the freezing point. I was therefore in that temperature which is most friendly to man; and the refined air I breathed, as if it had been entirely vital, communicated a vigour and agility to my limbs, and an activity and life to my ideas, which appeared to be of a celestial nature.

[*Spalanzani's Travels.*]

CHAP. XI.

VOLCANOES OF THE LIPARI ISLANDS.

To the northward of Sicily lies a cluster of small islands, almost all of which contain volcanoes, that of Stromboli being the chief. The crater of this last is peculiarly characterised by its frequent momentary eruptions of stones, which, in consequence of its being confined on the side of a hill, are thrown back by a recoil, and relapsing into the volcano supply it afresh with endless materials. The island of this group, which is named Vulcano, has a larger crater, but its

materials seem exhausted. The isle of Lipari, containing the town of the same name, presents vast rocks of volcanic glass; and it is from the hill called Campo Bianco, three miles from the town of Lipari, that Europe is chiefly supplied with pumice-stones for different purposes. Felicuda and Alicuda, the two extreme Liparian islands towards the west, display equal proofs of their having formerly contained volcanoes; and modern authors have discovered similar traces in the isle of Ischia, and in those of Penza to the north of the gulph of Naples; while that of Capri, to the south of the Neapolitan gulph, is supposed to be chiefly calcareous.

The best account we have received of the volcanic phenomena of Stromboli is that of Spalanzani, from whom we shall take leave to present our readers with the few following detached extracts.

I SHALL now proceed to relate what I observed relative to the volcano on the night of the 1st of October. My residence was in a cottage, on the north side of the island, about half a mile from the sea, and two miles from the volcano; but so situated that the cloud of smoke round the mountain scarcely permitted me to see the top of the fiery ejections. I employed more hours of the night in making my observations, than I permitted myself for repose; and the following is a brief summary of the principal appearances I noticed.

The south-east wind blew strong. The sky, which was clear, the moon not shining, exhibited the appearance of a beautiful aurora borealis over that part of the mountain where the volcano is situated, and which, from time to time, became more red and brilliant, when the ignited stones were thrown to a greater height from the top of the mountain. The fiery showers were then more copious, and the explosions which followed them louder, the strongest resembling those of a large mine which does not succeed properly, from some cleft or vent. Every explosion, however, slightly shook the house in which I was, and the degree of the shock was proportionate to the loudness of the sound. I do not believe that these shocks were of the nature of the earthquake; they were certainly to be ascribed to the sudden action of the fiery ejections on the air, which struck the small house in which I was, in the same manner as the discharge of a cannon will shake the windows of the neighbouring houses, and sometimes the houses themselves. A proof of this is, that the

THE ISLAND OF STROMBOLO

fiery showers always were seen a few seconds before the shock was felt, whereas the house was so near the volcano, that, had it been a real earthquake, no interval of time would have been perceptible.

Before the morning rose, the fiery light over the volcano increased so much, at three different times, that it illuminated the whole island, and a part of the sea. This light was each time but of short duration, and the showers of ignited stones were, while it lasted, more copious than before.

On the morning of the 2d of the same month, the south-east wind blew stronger than ever, and the sea was greatly agitated. The smoke of Stromboli formed a kind of cap round the top of the mountain, which descended much lower than on the preceding day. The phænomena were the same; but the convulsions of the volcano were more violent. The explosions were very frequent, but always with a hollow sound; and the ejected ashes reached the scattered dwellings of the people of the island. In the morning, the ground appeared very plentifully sprinkled with these ashes, as they are called by the natives; but on examination, I found that they were not properly ashes, but very finely triturated scoriæ, consisting of very small grains, of no determinate form, dry, and rough to the touch, and which crumble into powder under the finger. They are not far from a vitreous nature, in colour between a grey and a red, semi-transparent, and so light, that some will float on the water. Their levity proceeds from the great quantity of vesicles, or pores, which they contain, and which causes them, when viewed with the lens, to bear some resemblance to the sea production of unknown origin called savago (*favaggine*).

The islanders assured me that these eruptions were very inconsiderable compared with others which had formerly taken place, during which the ashes had, in a few hours, formed a covering over the ground and the houses of several inches thick; and the stones thrown out were scattered over the whole island, to the great damage of the vineyards and woods which were near the volcano, to which the flames communicated*.

---

* These showers of sand and pulverized scoriæ seem to be inseparable from volcanic eruptions, and to be copious in proportion as the latter are violent. Of this we have an example in the eruption of Etna in 1787, when the sand was carried as far as Malta. A prodigious space is well known to have been co-

As the day advanced, the hope I had entertained that I should be able immediately to visit the volcanic fires of Stromboli, greatly diminished; since I must have had to pass a large tract of the mountain entirely covered with smoke, which had extended itself so widely through the air, that it darkened the whole island. I deferred, therefore, my intended journey till the next day, should that prove more favourable, and employed myself in examining the principal productions of the place.

Wherever I placed my foot, I found the whole shore, to the east and north-east, composed of a black volcanic sand. This sand is an aggregate of fragments of shoerls, as has been remarked by M. Dolomieu; but when we view it with the lens, we discover, besides the shoerls, which are entirely opake, and are attracted by the magnet, a number of small transparent and vitreous bodies, of a yellowish green tincture, and which are insensible to the magnet. I was doubtful whether these were likewise fragments of shoerls, but of a different species, or whether they were volcanic chrysolites; their extreme minuteness not permitting me to ascertain their nature by any satisfactory experiment.

This sand extends into the sea, to the distance of more than a mile from the shore; as appeared from its adhering to the sunken plummet, when it had been previously covered with tallow: probably it reaches to a still greater distance.

The sea easily penetrates through this sand; for if any part of the shore be dug into a little depth, sea water is found, but rendered somewhat more fresh by having left a part of its salts in the sand; as happens to the same water when it issues, drop by drop, through a long tube filled with sand, through which is is filtered. The fishermen of Stromboli, when they are in want of fresh water, frequently dig wells on the shore, and drink the water these afford.

This sand, as has been already said, occupies that part of the island which fronts the east and the north-east, extending on the one side to the sea, into which it stretches, and on the other to the summit of the mountain. It owes its origin partly to the immediate ejections of it by the volcano, and partly to the pieces of scoriaceous lava thrown out by the same, which being, as has been said,

vered by the sand ejected from Etna, in the eruption of 1669. There is likewise no eruption of Vesuvius which is not accompanied by similar showers of sand and ashes.

extremely friable, and greatly abounding in shoerls, easily decompose and become pulverized in this sandy matter. In fact, nothing is more usual than to find in it fragments of this scoriaceous lava, of various sizes. This sand is found principally near the volcano, where both it, and the scoriaceous lavas from which it is formed, fall in the greatest quantities; but as, from its fineness, it is easily moveable, it is carried by the wind to the vallies and lower grounds quite to the sea.

This, however, is only the thin upper coating of those parts of Stromboli which it covers, as under it lies the firm texture of the island; I mean the solid lavas, which are visible on several steep descents, that have been stripped of the sand, either by the action of the rain-water, or that of the winds.

On the same day I made the circuit of a great part of the base of the island, which is about nine miles in circumference, and found the same solid constructure; a small tract of tufa, on the north side, excepted, which descends to the sea.

In this excursion, I carefully examined the course and direction of the lavas, and was convinced that they all had flowed from the steepest summit of the mountain, under different angles of inclination, passing one over another, and thus forming a succession of crusts, or strata, like, in some measure, the coatings of which an onion consists. In several places where the lava has entered the sea, these crusts may be seen lying one over the other, some ofthem broken or separated by the shock of the waves.

These facts strongly induced me to suspect that the crater of Stromboli had anciently been situated on the summit of the mountain, and that the lavas which had principally contributed to the production of the island had flowed from that crater.

The following night I returned to the same place, persuaded that I should see new objects to excite my admiration; and in fact, the scene I beheld, appeared to me as delightful and astonishing, as it was noble and majestic. The volcano raged with more violent eruptions, and rapidly hurled to a great height thousands of red hot stones, forming diverging rays in the air. Those which fell upon the precipice, and rolled down it, produced a hail of streaming fire, which illuminated and embellished the steep descent, and diffused itself around through a considerable space.

But, independent of these ignited stones, I remarked a vivid light

in the air, which hovered over the volcano, and was not diminished when that was at rest. It was not properly flame, but real light reverberated by the atmosphere, impregnated by extraneous particles, and especially by the ascending smoke. Besides varying in its intensity, it appeared constantly in motion, ascended, descended, dilated, and contracted, but constantly continued fixed to one place, that is, over the mouth of the volcano; and clearly shewed that it was caused by the conflagration within the crater.

The detonations, in the greater eruptions, resembled the distant roar of thunder; in the more moderate the explosion of a mine; and, in the least, they were scarcely audible. Every detonation was some seconds later than the ejection. This, likewise, was observable by day.

I remained that night two hours on the water at this place, and the eruptions were so frequent, and with such short intermissions, that they might be said to be continual.

During both these visits, thick showers of sand and fine scoriæ fell into the sea, and falling on my hat, which was of oil-cloth, made a noise like a small hail.

The five sailors who had the care of the boat in which I was, and some other natives of Stromboli who were with me, and whose occupation frequently brought them to that part of the sea, told me that the volcano might now be considered as very quiet; assuring me, that, in its greater fits of fury, red-hot stones were frequently thrown to the distance of a mile from the shore, and that, consequently, at such times, it was impossible to remain with a boat so near the mountain as we then were. Their assertion appeared to me sufficiently proved by a comparison of the size of the fragments thrown out in the explosions I now witnessed, with that of those which had been ejected in several former eruptions. The first (many of which had been stopped at the bottom of the precipice by other pieces of lava, and were scoriaceous lavas, approaching to a globose form) were not more than three feet in diameter; but many of the fragments thrown out at other times, of similar quality to them, and which lay in large heaps on the shore, were some four some five feet in diameter, and others even still larger.

Travellers have generally asserted that the volcano of Stromboli has for a long time discharged its fury into the sea, without causing either alarm or injury to the inhabitants of the island. The erup-

tions, however, fall equally on every side around the volcano; though at this place they only fall into the sea, and in that sense their assertion is well-founded.

But the people of Stromboli, and indeed almost all the inhabitants of the Eolian islands, entertain an opinion, equally amusing and paradoxical, by which they explain why that part of the sea which is contiguous to the precipice is never filled up, notwithstanding the immense quantities of stones which have been continually falling into it from time immemorial; where, instead of a peninsula having been formed by those stones, as might naturally have been expected, the sea is generally said to have no bottom. To explain this apparent paradox, these good folks affirm, with the most entire conviction that what they say is true, that the stones of the volcano which fall into the sea are attracted again by the mountain through secret passages; so that there is a constant circulation from the volcano to the sea, and the sea to the volcano.

I did not attempt to controvert their favourite hypothesis, which would have been to no advantage, and to no avail; but I caused that part of the sea to be sounded, and found it a hundred and twenty-four feet deep, which, though that is not a great depth in the Mediterranean, is certainly, in this place, somewhat surprising; as it was rather to be expected that the continual discharge of stones into it should have produced a little hill, which would at last have emerged above the waves.

With respect to the time when this volcano began to exert its activity, and to melt these rocks, we are profoundly ignorant, this being an epocha anterior to all history. We must be contented with the imperfect accounts the ancients have left us of the conflagrations of Stromboli, which did not burst forth in their time, but ages before. Of these accounts I shall proceed to give a concise view, this being the second enquiry it was proposed to make, and it will necessarily be brief, as the notices left us on this subject by the ancients are extremely few.

Eustatius, Solinus, and Pliny, inform us that the flames of Stromboli are less powerful than those of the other islands of Lipari, but that they exceed them in clearness and splendour. These writers, however, were only the copiers of Strabo, or perhaps some abridgment of him, in which he is copied incorrectly. We shall therefore have recourse to that celebrated Grecian geographer himself; who,

after having mentioned Lipari and Vulcano, and informed us that Stromboli likewise burns, tells us that the latter island, compared to the others, is inferior to them in the violent eruption of its flames, but that it exceeds them in their brightness.

It is evident, that by "the others," Strabo means Vulcano, which was the only one of the Eolian isles, besides Stromboli, in a state of conflagration in his time. When I compare Stromboli with Vulcano, I perceive that even now there is this difference between the two islands, that the flames of the former are much more resplendent and lively than those of the latter; but I cannot say that those of Stromboli are less violent, as the contrary is certainly the fact. We must, however, conclude, that in those ages the eruptions of Vulcano were very strong and frequent, which agrees with the testimony of Diodorus, and that of Agathocles as cited by the Scholiast on Apollonius; the former of whom asserts, that in his time Vulcano and Stromboli vomited great quantities of sand and burning stones; and the latter, that these two islands threw out fire, both by day and night.

There is another circumstance mentioned by the Sicilian historian which deserves notice. This is, that a wind issues from both these islands with a great noise. This in some measure agrees with the observations I made at Stromboli, and the attentive examiner will find it still more applicable to the other island.

Philip Cluverius, in his Sicilia Antiqua, speaking of Stromboli, tells us that its crater is situated at the summit of a mountain, from which it pours forth, both by day and by night, with a horrible noise, bright flames and great quantities of pumice *. In one of the plates prefixed to his work, this island is represented with the smoke rising from the summit of the mountain.

Nearly one hundred and seventy-three years have now elapsed since this author travelled in Sicily. Ought we then to conclude, that, at that time, the mouth of the volcano was situated at the summit of the mountain? Had the learned antiquary himself visited the island, I could not have objected to his evidence. But he not only does not say this, but the contrary may be inferred from his own words. Immediately after the passage I have already cited,

§ Strongule hodieque liquidissimam flammam, et pumices magna copia, ex vertice, ubi craterem habet noctes atque dies, cum fremitu horrendo, eructat.

he adds, "sed perpetui ejus ignes eminus navigantibus, nocte tantum, conspiciuntur. Fumum eorum candidissimum ex Italiæ pariter ac Siciliæ littoribus conspexi." It is therefore evident that he saw this volcano only from a distance, and that, consequently, his assertion, that the fiery crater was situated at the summit, is not to be depended on. What he has said of the pumices then thrown out by it, he may have taken on the credit of some of the natives who gave him that information, and who confounded the scoriaceous lavas with pumices; or it may in fact be true, since under the scoriæ and lavas of Stromboli, scattered pumices are found, as I have observed above.

From the authorities above adduced it appears, therefore, that the most ancient accounts of the conflagrations of Stromboli, transmitted to us by history, are prior to the Christian era by about 290 years, the date of the reign of Agathocles, the celebrated tyrant of Syracuse. This volcano burned likewise in the times of Augustus and Tiberius, when Diodorus and Strabo flourished. But after this latter period, a long series of ages succeeds, during which, from want of documents, we are ignorant of the state of Stromboli; and it is not until the seventeenth century, that we again know with certainty that it ejected fire; though it is not improbable that it continued to burn likewise during the times in which we find no mention of it in history: on which supposition, its uninterrupted conflagration, for so great a length of time, must indeed appear astonishing. Yet, though it should have ceased for several ages, we know from various public testimonies, that its continued eruptions cannot have lasted less than two hundred years.

Here our curiosity may naturally be excited by the question: what are the substances which, without diminution, have nourished, during such a number of years, and still continue to feed, these fires? I do not perceive that there is any reason to suppose them different from those which furnish fuel to the intermitting volcanoes, except that their source appears to be inexhaustible. It is believed, with much reason, that sulphur produces and continues volcanoes; and wherever these mountains burn, we have indisputable proofs of its presence. Still more effectually to explain these conflagrations, petroleum has likewise been called in aid; and, in fact, it has sometimes been found to issue in the neighbourhood of a volcano, of

which Vesuvius is an example*. The clouds of thick black smoke, which frequently rise into the air from the mouths of volcanoes, and the unctuosity and sootiness which are said to be found in the recent scoriæ, seem likewise to be evident indications of some bituminous sublimate.

That Stromboli contains within its deep gulphs and recesses an immense mine of burning sulphur, we can entertain little doubt, when we consider the streams of smoke, of extraordinary whiteness (a colour which constantly accompanies sulphureous fumes), that rise on the west side of the island, and the smell of sulphur, not only perceptible from them, but from the large cloud of smoke which overhangs the summit of the mountain. The small pieces of that mineral produced near the apertures whence those fumes arise, are likewise another proof. But of the presence of petroleum, and its effects, I have never perceived the least sign. Besides that no vein of it is found in the island, nor any ever seen swimming on the sea which surrounds Stromboli, as I was assured by the general testimony of the inhabitants, the smell of this bitumen is no where sensible, though naturally it is very acute. I have frequently visited the sources of petroleum, at Monte Zibio, in the territory of Modena, and I could always perceive the smell of their penetrating vapours, at the distance of several hundred paces, before I reached them. I therefore conclude, that these vapours must have been much more sensible at Stromboli, as they would have been much more active, had petroleum actually burned within its gulph. I have likewise examined, with the greatest attention, the scoriæ thrown out by the volcano, and while they were very hot; but I never could perceive that they emitted, either from their surface or within their pores and cavities, the least smell of that bituminous substance, or that they any where exhibited any unctuous humidity. As I knew that the smoke which exhales from burning petroleum is of a blackish hue, I suspected that the thick and dark column of smoke, which arose to the east of the volcano, might be a sign of its presence; but, on a nearer approach, I perceived that its darkness proceeded from aqueous vapours which were mixed with it, and which,

* Serao, Istoria dell' Incendio del Vesuvio, del 1737. Bottis, Istoria di varj Incendj del Monte Vesuvio.

by my continuing a short time in it, rendered my clothes damp and wet.

Shall we then affirm that the fires of Stromboli receive no kind of aliment from this bitumen? Notwithstanding the observations I have stated, I would not venture confidently to deduce such a conclusion; since it is possible that the petroleum may burn under the mountain, at so great a depth that its vapours may not reach to the top, but may be dispersed and consumed by the fire, and the immense mass of liquefied matter, which probably extends from the crater to the lowest roots of the island.

But though we should not admit the existence of this oil within the deep recesses of the mountain, I do not perceive but the sulphur alone may be sufficient for the nourishment of the volcano, when its flame is animated by oxygenous gas, the presence of which, in volcanic abysses, seems undeniable, from the substances they contain proper to generate it, when acted on by the fire. The long duration without intermission, therefore, of these conflagrations, may be very sufficiently explained by the immense quantities of sulphur, or, to speak more properly, sulphures of iron which we must necessarily suppose contained in the bowels of the mountain; a supposition rendered the more probable by the prodigious subterranean accumulations of this mineral which have been discovered in various parts of the globe.

[*Spalanzani. Dolomieu, Isles Ponces.*]

CHAP. XII.

VOLCANOES OF ICELAND.

SECTION I.

Introductory Remarks.

ICELAND, perhaps the *Ultima Thule* of Virgil, about two hundred and sixty miles long, and two hundred broad, forming an extensive portion of the Danish dominions, evinces in every quarter a volcanic origin, and abounds in volcanoes, sulphur, subterraneous fires, and geysers, or eruptive hot springs. Its highest mountains, clothed with perpetual snows, are called Jokuls, and of these Snæfell, in the south-western part of the island, is the loftiest, being calculated at six thousand eight hundred and sixty feet above the level of the sea. Its principal rivers lie towards the east, some of which are white with lime, and others tainted with sulphur. Its calcareous spar has been celebrated ever since the days of Newton for its double refraction. This remote and barren country has been not unfrequently subject to dreadful mortalities from epidemics: the pestilence of this kind that depopulated the island, in the middle of the fourteenth century, was called the Black Death; and according to Cattereau, a murrain in 1784 carried off not less than nineteen thousand four hundred and eighty-eight horses, six thousand eight hundred beeves, and twelve thousand nine hundred and forty-seven sheep. This account, however, seems too highly charged, for it exceeds the general average of the cattle of the entire island. Since it has appertained to the Danish crown, a colony endeavoured to ameliorate its wretched situation by migrating to Greenland, about two hundred miles distant, and which is now usually placed in the American quarter of the world; of its success, however, we know nothing, for the eastern coast, on which it probably effected a landing, has since been so extensively blocked up by augmenting sheets of ice, that the colony has never since been explored. —Yet to this wretched verge of the habitable globe was literature compelled to retire in the eleventh and twelfth centuries: here

learning, driven at that period from every other part of Europe, flourished; poetry was cultivated; and the mythology of the northern nations was first reduced into a systematic form. While feudal tyranny, by the blood-shed and oppression to which it every where gave birth, retained the finest countries of the civilised globe in a state of barbarism; liberty and peace, with science and the arts in their train, took refuge in this inhospitable clime; and found, on the confines of the polar circle, an asylum which the plains of France and Italy could not afford them; a memorable example how much worse the sufferings are produced by art than those produced by nature.—*Editor*.

SECTION II.

Description of Hekla.

By Sir George Steuart Mackenzie, *Bart.*

We now came into the plain from which Hekla rises; but we had no view of the mountain as we approached, as it was covered with clouds. We passed through lava which had been exposed to view by the blowing of the sand that covers so great an extent of this country. Storuvellir is situate in the midst of this tract; and round it there is a great deal of excellent grass. The provost had a large stock of old hay, which, without any report in his favour as a good rural economist, would have been a sufficient proof of his merit. He received us with great kindness, but annoyed us a little by the excess of his attention or curiosity. The provost is reputed rich; and it is said that he has made his fortune entirely by his good management of his farm, on which we saw a considerable flock of sheep, and some cows. The winter provision of stock-fish kept in the church, was no advantage to its atmosphere, which can undergo little purification; for the windows of the churches, in general, did not seem to be made to open.

The weather being still foggy, we could not see Hekla as we approached. On the 1st August, we passed through lava of the same description as that pervading every part of this flat district we had travelled over. We crossed the river called Wester Rangaa, the water of which is perfectly transparent, and flows along the foot of Hekla, on the west side. The bed of this river is very remarkable, being formed of rugged masses of lava, which being here and there

elevated in peaks, cause great rapidity in the stream. Owing to the clefts in the lava, it is very dangerous to attempt crossing the river at this place without a guide. The provost was very obliging, and gave us instructions in what manner to follow him across; and as soon as he saw us safe, he took leave and returned to Storuvellir.

On the end of a long ridge, running nearly north and south, close to the base of Hekla, is a small farm, called Naifurholt. Here we halted; and the grass having been recently mown, we found an admirable station for our tent. The cottager, Jon Brandtson, whom we found to be the most obliging and active Icelander we had met with, was not long in making his appearance, and ministering to our wants. He told us that he could guide us to a place where there was a great quantity of Iceland agate, or obsidian; a piece of information the most welcome we had for a long time received. That substance was one of the chief objects of our mineralogical researches; and not having before met with it, we had given up all thoughts of seeing it in its place; when honest Brandtson, observing us employed with the minerals we had already collected, brought a mass of obsidian to us, and relieved us from a most severe mortification. He told us that the place where he had seen great quantities of that substance, was situate near the Torfa Jokul, and distant a long day's journey from Naifurholt. Our time was now limited; but we had no hesitation in making up our minds to endure considerable fatigue, in order to visit a spot so interesting to us; and even, in case of need, to relinquish the project of ascending the far-famed Hekla; and, accordingly, we resolved to undertake this expedition next day, as the weather did not appear favourable for the ascent of the mountain. Having made preparations for both adventures, we went early to bed.

Finding, at two o'clock in the morning, that Hekla was entirely obscured by fog, we mounted our horses; and each taking a spare one, we departed, Brandtson leading the way. In the course of our journey, as the clouds dispersed, we had different views of the mountain, which is completely covered with slags. Few streams of lava seem to have taken their course on the west and north sides; indeed, we saw distinctly only one. Hekla, like Snæfell Jokul, terminates a long group of comparatively low hills. Viewed from the westward, when Eyafialla, Tinfialla, and other Jokuls beyond it are in sight, the mountain makes no great figure; but from the

east and south, it appears to rise out of the hills surrounding it, and is very conspicuous.

Our road towards the obsidian lay between the Rangaa and the Thiorsaa, the course of which is nearly from north-east to south-west. This last-mentioned river here rolls its large turbid stream over rugged masses of lava rising abruptly from its bed; and in its efforts to overcome the obstruction thus occasioned, dashes among the rocks, forming impetuous rapids and falls. Great quantities of alluvial sand appeared disposed in strata in different parts of the country through which we passed; and in other places there were extensive accumulations of volcanic sand composed of pumice and cinders.

Having recrossed the Rangaa, we entered a wide plain, bounded by Hakla and the adjacent mountains on one side, and by a lofty, precipitous, and broken ridge on the other, the surface being completely covered with lava, sand, or minute fragments of scoriæ and pumice. The lava which has flowed over the plain, the termination of which we could not see, appears to have been remarkably rough, from the numerous sharp-pointed masses rising out of the loose sand and slags, the accumulation of which has rendered it passable. We travelled about fourteen miles, judging of the distance by the time our journey occupied, and then halted at the foot of a large mass of lava, and changed our horses; stopping no longer than was necessary for shifting our saddles. The subsequent part of our route though still through an extremely desolate country, was rendered more easy by the absence of lava, and somewhat less forbidding by the appearance of thinly-scattered vegetation on the vallies, and on the sides of some of the hills. Ere long we found ourselves inclosed in a hollow among the mountains, from which there was no apparent outlet; but following the steps of our guide, we pursued a winding course, passing through a number of rivulets of very thick muddy water which proceeded from under the snow on the mountains*.

As we went along we observed several craters in low situations, from which flame and ejected matter had proceeded during the convulsions to which this part of the island has been particularly sub-

* Extensive masses of clay are not uncommon in volcanic districts, especially where there are hot springs, or where such have existed; and this may account for the peculiar colour of most of the large rivers of Iceland.

jected. After having advanced about fifteen miles farther, and traversed a part of that immense waste which forms the interior of Iceland, and is partially known only to those who go in search of strayed sheep, we descended by a dangerous path into a small valley, having a small lake in one corner, and the extremity opposite to us bounded by a perpendicular face of rock resembling a stream of lava in its broken and rugged appearance. While we advanced, the sun suddenly broke through the clouds, and the brilliant reflection of his beams from different parts of this supposed lava, as if from a surface of glass, delighted us by an instantaneous conviction, that we had now attained one of the principal objects connected with the plan of our expedition to Iceland. We hastened to the spot, and all our wishes were fully accomplished in the examination of an object which greatly exceeded the expectations we had formed. The mineralogical facts which here presented themselves to our notice, will be described in a subsequent chapter.

On ascending one of the abrupt pinnacles which rose out of this extraordinary mass of rock, we beheld a region, the desolation of which can scarcely be paralleled. Fantastic groups of hills, craters, and lava, leading the eye to distant snow-crowned Jokuls; the mist rising from a waterfall; lakes embosomed among bare, bleak mountains; an awful profound silence; lowering clouds; marks all around of the furious action of the most destructive of elements; all combined to impress the soul with sensations of dread and wonder. The longer we contemplated this scene, horrible as it was, the more unable we were to turn our eyes from it; and a considerable time elapsed, before we could bring ourselves to attend to the business which tempted us to enter so frightful a district of the country. Our discovery of obsidian afforded us very great pleasure, which can only be understood by zealous geologists; and we traversed an immense and rugged mass of that curious substance, with a high degree of satisfaction; though various circumstances prevented our tracing it so fully as we wished.

Towards the east, at the distance of three or four miles, we observed a very large circular hollow, the sides of which were chiefly of a bright red colour; from which circumstance, and its general appearance, we concluded that it was the crater of an extinct volcano. The waterfall, the noise of which we distinctly heard, though at the distance of several miles, was formed by the Tunaa, a large

river, which takes its course in this part of the country, and joins the Thiorsaa.

Brandtson told us that he had never been farther in this direction; and pointed out to us the Sprangè Sands, a vast plain, consisting of volcanic matter, which is stretched over a great part of those inhospitable regions already mentioned. Numerous obstacles present themselves to any person who may think of entering this dreadful country, among which the want of food for horses is the principal. The rivers, lakes, streams of lava, all the horrors of nature combined, oppose every desire to penetrate into these unknown districts; and the superstitious dread in which they are held by the natives is readily excused, the instant they are seen, even from afar. We saw the lake called Fiske Vatn, and the summits of several Jokuls, in the distance, which will be more particularly noticed afterwards, as we observed them more distinctly from another station.

Before we had satisfied our curiosity, rain fell in torrents, and continued to do so for an hour or two. We had not proceeded far on our return to Naifurholt, when it ceased, and was succeeded by a very thick fog, through which Brandtson guided us safely; and we reached our tents soon after twelve o'clock at night, having been absent twenty-two hours, during seventeen of which we were on horseback.

After the fatigue we had undergone in our excursion towards the Torfa Jokul in search of obsidian, we did not expect to find ourselves sufficiently refreshed to attempt ascending Mount Hekla on the following day; but, as we had been long in the constant habit of enduring daily hardships, we rose at an early hour on the third of August, quite alert; and, on seeing the whole of the mountain free from clouds, we were soon ready to finish our labours, by ascending Hekla, and attaining the summit of a mountain whose fame has spread to every quarter of the world. At ten o'clock, we were ready; and Brandtson having collected our horses, we mounted them, and began our expedition under circumstances as favourable as we could wish. We rode through sand and lava about three miles, when the surface became too rugged and steep for horses. Our guide proposed leaving the poor animals standing till we returned; but though they would not have stirred from the spot, we sent them back, not chusing that such valuable and steady servants

should remain a whole day without food. We now proceeded a considerable way along the edge of a stream of lava, and then crossed it where it was not very broad, and gained the foot of the south end of the mountain. From this place we saw several mounts and hollows from which the streams of lava below appeared to have flowed. While we had to pass over rugged lava, we experienced no great difficulty in advancing; but when we arrived at the steepest part of the mountain, which was covered with loose slags, we sometimes lost at one step, by their yielding, a space that had been gained by several. In some places we saw collections of black sand, which, had there been any wind, might have proved extremely troublesome. The ascent now became very steep, but the roughness of the surface greatly assisted us.

Before we had reached the first summit, clouds surrounded us, and prevented our seeing farther than a few yards. Placing implicit confidence in our guide, we proceeded, and having attained what we thought was the nearest of the three summits, we sat down to refresh ourselves, when Brandtson told us that he had never been higher up the mountain. The clouds occasionally dividing, we saw that we had not yet reached the southern summit. After having passed a number of fissures, by leaping across some, and stepping along masses of slags that lay over others, we at last got to the top of the first peak. The clouds now became so thick, that we began to despair of being able to proceed any farther. Indeed it was dangerous even to move; for the peak consists of a very narrow ridge of slags, not more than two feet broad, having a precipice on each side many hundred feet high. One of these precipices forms the side of a vast hollow which seems to have been one of the craters. At length the sky cleared a little, and enabled us to discover a ridge below, that seemed to connect the peak we were on with the middle one. We lost no time in availing ourselves of this opportunity, and by balancing ourselves like rope-dancers, we succeeded in passing along a ridge of slags so narrow that there was hardly room for our feet. After a short, but very steep ascent, we gained the highest point of this celebrated mountain.

We now found that our usual good fortune had not yet forsaken us; for we had scarcely begun to ascend the middle peak, when the sky became clear, and we had a full view of the surrounding country. Towards the north it is low, except where a Jökul here and there towers into the regions of perpetual snow. Several large lakes ap-

peared in different places, and among them the Fiske Vatn was the most conspicuous. In this direction we saw nearly two-thirds across the island. The Blæfell and the Lange Jokuls, stretched themselves in the distance to a great extent, presenting the appearance of enormous masses of snow heaped up on the plains. The Skaptar Jokul, whence the great eruption that took place in the year 1783 broke forth, bounded the view towards the north-east. It is a large, extensive, and lofty mountain, and appeared to be covered with snow to the very base. On the side next to us, though at a distance of about forty miles, we plainly discerned a black conical hill, which very probably may be one of the craters that were formed during the eruption. The Torfa, Tinfialla, and Eyafialla Jokuls, limit the view of the eastern part of the country. Towards the south, the great plain we had passed through seemed as if stretched under our feet, and was bounded by the sea. The same valley was terminated towards the west by a range of curiously-peaked mountains, those in the neighbourhood of Thingvalla, and to the north and west of the Geysers.

The middle peak of Hekla forms one side of a hollow, which contains a large mass of snow at the bottom; and is evidently another crater. The whole summit of the mountain is a ridge of slags, and the hollows on each side appear to have been so many different vents from which the eruptions have from time to time issued. We saw no indications that lava had flowed from the upper part of the mountain; but our examination, from the frequent recurrence of fog, was unavoidably confined.

After we had satisfied ourselves in surveying the surrounding country, we began to collect specimens of the slags, and perceived some of them to be warm. On removing some from the surface, we found those below were too hot to be handled; and on placing a thermometer amongst them, it rose to 144°. The vapour of water ascended from several parts of the peak. It had been remarked to us by many of the inhabitants, that there was less snow on Hekla at this time than had been observed for many years. We supposed, therefore, that the heat now noticed might be the recommencement of activity in the volcano, rather than the remaining effects of the last eruption which took place in the year 1766.

The crater, of which the highest peak forms a part, does not much exceed a hundred feet in depth. The bottom is filled by a

large mass of snow, in which various caverns had been formed by its partial melting. In these the snow had become solid and transparent, reflecting a bluish tinge; and their whole appearance was extremely beautiful, reminding us of the description of magic palaces in eastern tales.

At the foot of the mountain, the thermometer at half past nine o'clock stood at 59°. At eleven, it was at 55°, and at four, on the top, at 39°.

Our descent was greatly retarded by thick fog; and we found it much more hazardous than the ascent. We missed our way and were under the necessity of crossing the lava we had passed in our way up, at a place where it had spread to a much greater breadth, and, from the rapidity of the slope along which it had flowed, had become frightfully rugged.

Mount Hekla has acquired a degree of distinction among volcanoes, to which it does not seem to be entitled. It is far behind Etna and Vesuvius, both in the frequency and magnitude of its eruptions. We could not distinguish more than four streams of lava; three of which have descended on the south and one on the north side; but there may be some streams on the east side, which we did not see. The early eruptions of this mountain do not seem to have been regularly recorded. Olafson and Paulson say, that after careful research they found that the number of eruptions amounted to twenty two; and none are recorded as having happened before the year 1004. There were eruptions in the years 1137, 1222, 1300, 1341, 1362, 1389, 1538, 1619, 1636, and 1693. Flames appeared in the neighbourhood in 1728. In 1554, there were eruptions from the mountains to the eastward; and in 1754, flames burst out to the westward. From the mountain itself, no eruption took place between the years 1693 and 1766, an interval of seventy-three years; and during this last period of activity, no lava was thrown out. The following year, flames broke out afresh, and the mountain was not perfectly quiet in the year 1768: since that time it has remained inactive. We had no opportunity of measuring the height of Mount Hekla; but we have been informed by Sir J. Stanley that the elevation which resulted from his observations, was 4,300 feet, and this, from different circumstances, we believe to be correct.

In the year 1755, a terrible eruption proceeded from the moun-

tain called Kattlagiau Jokul, which is situate to the eastward of Eyafialla. From the accounts of this eruption, it does not appear that any lava flowed; but immense torrents of water carried destruction before them through the neighbouring country; and ignited stones and ashes were thrown in all directions. The electrical phænomena that accompanied this eruption, seem to have been very tremendous; several people and cattle having been killed by the lightning. The mountain continued in a state of violent activity during a whole month; and, indeed, it may be said to have been so during a whole year; for, between January and September of the year 1756, five different eruptions took place. We heard a report, that early in the summer the inhabitants in the neighbourhood had some reason to apprehend an impending eruption; but we could get no distinct account of the symptoms that had been observed. The earliest eruption of Kattlagiau, appears to have happened about the year 900; and, since that period, to the great one in 1755, only five have occurred.

It is mentioned, in the history of Iceland during the eighteenth century, that an eruption took place from Eyrefa Jokul, in the south-east part of the island, in the year 1720; and one from the lake of Grimsvatn in the year 1716*.

In the north-east quarter of Iceland, near a large lake called Myvatn, is Mount Krabla, which became remarkable by dreadful eruptions of lava that proceeded from it between the years 1724 and 1730. Some of the streams of lava flowed into the lake, destroyed the fish, and almost dried it up. There were eruptions also from the mountains round Krabla; and an extensive district of inhabited country was laid waste. At a place called Reikiahlid, near Krabla, sulphur is found in the same circumstances as that at Krisuvik, but in larger quantities. It was from the former place that most of the sulphur brought from Iceland was exported.

In the year 1000, an eruption took place in the Guldbringè Syssel.

* I am uncertain of the position of this lake. There is only one of the name which I could find marked on the maps of Iceland, but, from the circumstance of all the most recent eruptions having proceeded from the southern part of the island, I suspect that there may be a lake of the same name somewhere to the eastward of Markarfliot; and, since my return home, I have received such information as leads me to believe my conjecture right.

Another broke out near Reikianes in the year 1340; and one is said to have been seen at a great distance in the sea, in the year 1583, similar to that which was observed preceding the great eruption of 1783.

The total number of recorded eruptions appears to be the following:

From Hekla, since the year	- -	1004, inclusive	- 22
From Kattlagiau Jokul	- - -	900,	- 7
From Krabla,	- - - -	1724,	- 4
In different parts of the Guldbringè Syssel		1000,	- 3
At sea,	- - - - - -	1583,	- 2
From the lake Grimsvatn, in	- -	1716,	- 1
From Eyafialla Jokul * in	- -	1717,	- 1
From Eyrefa Jokul, in	- - -	1720,	- 1
From Skaptar Jokul, in	- - -	1783,	- 1
			42

In chronological order, the different eruptions mentioned by Icelandic authors stand recorded thus: In the years 900, 1000, 1104, 1137, 1222, 1300, 1340, 1341, 1362, 1389, 1422, 1538 (Vesuvius erupted the same year), 1554 (Etna), 1583, 1619, 1636 (Etna), 1693 (Vesuvius, 1692; Etna, 1694), 1716, 1717 (Vesuvius), 1720, 1724, 1728, 1730 (Vesuvius), 1754 (Vesuvius), 1755 (Etna), 1756, 1766 (Etna and Vesuvius), 1771, and 1772, flames seen on Hekla; 1783. Thus it appears, that many of the eruptions that are known to have taken place since Iceland was inhabited, have not been particularly noticed; and it is very probable, that numerous eruptions of less note have been passed over. We may reckon active all those mountains which have burned within the last century. Of these there are six;—Hekla, Krabla, Kattlagiau, Eyafialla, Eyrefa, and Skaptar, Jokuls.

The most recent eruption that took place in Iceland seems also to have been the most awful. It proceeded from the low country near

* This mountain is often called Oster Jokul (eastern Jokul), in contradistinction to Snæfell Jokul, which is called western. The eruption of the eastern Jokul in 1717, and the one from Grimsvatn, are recorded by Mr. Stephenson in his History of Iceland during the eighteenth century.

the Skaptar Jokul in the year 1783. Mr. Stephenson of Indreholm was ordered by the King of Denmark to proceed from Copenhagen, where he happened to be during the eruption, and to visit the district, that his Majesty might be enabled to alleviate the distresses occasioned by the eruption. That gentleman has published a laboured account of the whole; but, although there is no doubt of the eruption having been one of the most terrible in the annals of volcanoes, he seems to have depended too much on reports and information, which appear to be exaggerated. He himself told us, that the lava was so hot at the time he approached it, which was about a year after the eruption, that it could not be examined, and that it has never been traced to its source. Another account has been written, which, from what we heard in Iceland, is the most correct. It is to be lamented that the present state of the Icelandic press, prevents its being given to the public *.

The whole tract between Hekla and Krabla is a desert quite impassable and unknown; and there is still subsisting a ridiculous notion that it is inhabited by a tribe of robbers. Did such people really exist, and did they know the dread which they inspire, they might easily procure more comfortable quarters.

No single volcanic mountain which we saw, appeared to have thrown out much lava. Probably this has been owing to the vast number of apertures which have given vent to the rage of subterraneous heat. In other countries, where it has for ages continued to explode from one or two mountains, the lava is confined to one place, and is abundant.

There is no country in the known world where volcanic eruptions have been so numerous as in Iceland, or have been spread over so large a surface. No part of the island is wholly free from the marks of volcanic agency; and it may be truly called the abode of subterraneous heat. Various volcanic mountains and streams of lava, are mentioned as existing in the eastern and northern districts, by

* I have accidentally procured a map, which appears to have belonged to some description of this dreadful event, and by which it appears, that the lava burst out at three different points about eight or nine miles distant from each other, and spread in some places to a breadth of thirty miles. The extent from north to south as far as the lava seems to have been observed, is upwards of forty miles, and it is known to have flowed much farther; though it has not been traced.

Eggart Olafson, in his *Enarrationes Historicæ de Natura et Constitutione Islandiæ*. In the north west quarter, in the district of Isafiord, there is a volcanic mountain called Glama, which he describes as rivalling the magnitude of the Snæfell Jokul. Thus it appears that the force of subterraneous fire has been exerted upon every part of this extensive island; and when we consider the eruptions that have been seen at a distance in the sea, we are safe in estimating, that, in this part of the earth, one continued surface of not less than sixty thousand square miles has been subjected to that engine of destruction.

[*Sir George Mackenzie's Travels in the Island of Iceland.*]

SECTION III.

Sulphur Mountains.

[By the Same.]

HAVING taken an early breakfast, we set out towards the Sulphur Mountain, which is about three miles distant from Krisuvik. At the foot of the mountain was a small bank composed chiefly of white clay and some sulphur, from all parts of which steam issued. Ascending it, we got upon a ridge immediately above a deep hollow, from which a profusion of vapour arose, and heard a confused noise of boiling and splashing, joined to the roaring of steam escaping from narrow crevices in the rock. This hollow, together with the whole side of the mountain opposite, as far up as we could see, was covered with sulphur and clay, chiefly of a white or yellowish colour. Walking over this soft and steaming surface we found to be very hazardous; and we were frequently very uneasy when the vapour concealed us from each other. The day, however, being dry and warm, the surface was not so slippery as to occasion much risk of our falling. The chance of the crust of sulphur breaking, or the clay sinking with us, was great; and we were several times in danger of being much scalded. Mr. Bright ran at one time a great hazard, and suffered considerable pain from accidentally plunging one of his legs into the hot clay. From whatever spot the sulphur is removed, steam instantly escapes; and, in many places, the sulphur was so hot that we could scarcely handle it. From the smell, we perceived that the steam was mixed with a small quantity of sulphurated hydrogen gas. When the thermometer was sunk a few inches into the clay, it rose generally to within a few degrees of the boiling point. By stepping cautiously, and avoiding every little

hole from which steam issued, we soon discovered how far we might venture. Our good fortune, however, ought not to tempt any person to examine this wonderful place, without being provided with two boards, with which every part of the banks may be traversed in perfect safety. At the bottom of this hollow we found a cauldron of boiling mud, about fifteen feet in diameter, similar to that on the top of the mountain, which we had seen the evening before; but this boiled with much more vehemence. We went within a few yards of it, the wind happening to be remarkably favourable for viewing every part of this singular scene. The mud was in constant agitation, and often thrown up to the height of six or eight feet. Near this spot was an irregular space filled with water boiling briskly. At the foot of the hill, is a hollow formed by a bank of clay and sulphur, steam rushed with great force and noise from among the loose fragments of rock.

Further up the mountain, we met with a spring of cold water, a circumstance little expected in a place like this. Ascending still higher, we came to a ridge composed entirely of sulphur and clay, joining two summits of the mountain. Here we found a much greater quantity of sulphur than on any other part of the surface we had gone over. It formed a smooth crust from a quarter of an inch to several inches in thickness. The crust was beautifully crystallized, and immediately beneath it we found a quantity of loose granular sulphur, which appeared to be collecting and crystallizing as it was sublimed along with the steam. Sometimes we met with clay of different colours, white, red, and blue, under the crust; but we could not examine this place to any depth, as, the moment the crust was removed, steam came forth, and proved extremely annoying. We found several pieces of wood, which were probably the remains of planks that had been formerly used in collecting the sulphur, small crystals of which partially covered them. There appears to be a constant sublimation of this substance; and were artificial chambers constructed for the reception and condensation of the vapours, much of it might probably be collected. As it is, there is a large quantity on the surface; and, by searching, there is little doubt that great stores may be found. The inconvenience proceeding from the stream issuing on every side, and from the heat, is certainly considerable; but, by proper precautions, neither would be felt so much as to

render the collection of the sulphur a matter of any great difficulty. The chief obstacle to working these mines, is their distance from a port whence the produce could be shipped. But there are so many horses in the country, whose original price is trifling, and whose maintenance during summer costs nothing, that the conveyance of sulphur to Reikiavik presents no difficulties which might not probably be surmounted.

Below the ridge on the farther side of this great bed of sulphur, we saw a great deal of vapour escaping with much noise. We crossed to the side of the mountain opposite, and found the surface sufficiently firm to admit of walking cautiously upon it. We had now to walk towards the principal spring, as it is called. This was a task of much apparent danger, as the side of the mountain, for the extent of about half a mile, is covered with loose clay, into which our feet sunk at every step. In many places there was a thin crust, below which the clay was wet, and extremely hot. Good fortune attended us; and without any serious inconvenience, we reached the object we had in view. A dense column of steam, mixed with a little water, was forcing its way impetuously through a crevice in the rock, at the head of a narrow valley, or break in the mountain. The violence with which it rushes out is so great, that the noise, thus occasioned, may often be heard at the distance of several miles; and, during night, while lying in our tent at Krisuvik, we more than once listened to it with mingled awe and astonishment. Behind the column of vapour was a dark-coloured rock, which gave it its full effect.

It is quite beyond our power to offer such a description of this extraordinary place, as to convey adequate ideas of its wonders or its terrors. The sensations of a person, even of firm nerves, standing on a support which feebly sustains him, over an abyss where, literally, fire and brimstone are in dreadful and incessant action; having before his eyes tremendous proofs of what is going on beneath him; enveloped in thick vapours; his ears stunned with thundering noises; must be experienced before they can be understood.

[*Travels in the Island of Iceland.*]

SECTION IV.

Volcanic Peak of Snæfell Jokul.

[From Mr. BRIGHT's Narration.]

AFTER a hesitation of an hour or two, on account of the doubtful appearance of the day, Mr. Holland and myself, with our interpreter, and one of our guides, who was very desirous of accompanying us, put ourselves under the direction of a stout Icelander, who undertook to be our leader in the ascent of the Jokul. He, however, honestly confessed, that he had never been higher up the mountain than the verge of the perpetual snow, as the sheep never wandered beyond that limit; but this was also the case with the other inhabitants of the district. Every one of us provided himself with an Iceland walking staff, furnished with a long spike at the end; and, in case of need, we carried some pairs of large coarse worsted stockings of the country manufacture. We likewise had our hammers and bags for specimens, a compass and thermometer, a bottle of brandy, with some rye-bread and cheese.

Thus equipped, we set forward on our march; and having passed two or three cottages, whose inhabitants gazed with wonder at our expedition, we directed our course in nearly a straight line towards the margin of the snow. The nearer we approached it, vegetation became more and more scanty, and at length almost entirely disappeared. After walking at a steady pace for two hours, in which time we had gone about six miles, we came to the first snow, and prepared ourselves for the more arduous part of our enterprize. The road being now alike new to all, we were as compétent as our guides to the direction of our further course. The summits of all the surrounding mountains were covered with mist; but the Jokul was perfectly clear; and as the sun did not shine so bright as to dazzle our eyes with the reflection from the snow, we entertained good hopes of accomplishing our purpose. During the first hour the ascent was not very difficult, and the snow was sufficiently soft to yield to the pressure of our feet. After that time the acclivity was steeper, the snow became harder, and deep fissures appeared in it, which we were obliged to cross, or to avoid by going a considerable way round. These fissures presented a very beautiful spectacle;

they were at least thirty or forty feet in depth, and though not in general above two or three feet wide, they admitted light enough to display the brilliancy of their white and rugged sides. As we ascended, the inferior mountains gradually diminished to the sight, and we beheld a complete zone of clouds encircling us, while the Jokul still remained clear and distinct. From time to time the clouds, partially separating, formed most picturesque arches, through which we descried the distant sea, and still farther off, the mountains on the opposite side of the Breidè-Fiord, stretching northwards towards the most remote extremity of the island.

In the progress of our ascent, we were obliged frequently to allow ourselves a temporary respite, by sitting down for a few minutes on the snow. About three o'clock, we arrived at a chasm, which threatened to put a complete stop to our progress. It was at least forty feet in depth, and nearly six feet wide; and the opposite side presented a face like a wall, being elevated several feet above the level of the surface on which we stood; besides which, from the falling in of the snow in the interior of the chasm, all the part on which we were standing was undermined, so that we were afraid to approach too near the brink lest it should give way. Determined, however, not to renounce the hope of passing this barrier, we followed its course till we found a place that encouraged the attempt. The opposite bank here was not above four feet high, and a mass of snow formed a bridge, a very insecure one indeed, across the chasm. Standing upon the brink, we cut with our poles three or four steps in the bank on the other side, and then, stepping as lightly as possible over the bridge, we passed one by one to the steps, which we ascended by the help of our poles. The snow on the opposite side became immediately so excessively steep, that it required our utmost efforts to prevent our sliding back to the edge of the precipice, in which case we should inevitably have been plunged into the chasm. This dangerous part of our ascent did not continue long; and we soon found ourselves on a tolerably level bank of snow, with a precipice on our right about sixty feet perpendicular, presenting an appearance as if the snow on the side of the mountain had slipped away, leaving behind it the part on which we stood. We were now on the summit of one of the three peaks of the mountain; that which is situated farthest to the east. We beheld immediately be-

fore us a fissure greatly more formidable in width and depth than any we had passed, and which, indeed, offered an insuperable obstacle to our further progress. The highest peak of the Jokul was still a hundred feet above us; and after looking at it some time, with the mortification of disappointment, and making some fruitless attempts to reach, at least, a bare exposed rock which stood in the middle of the fissure, we were obliged to give up all hope of advancing further.

The peak of the Jokul we had now attained, is about 4,460 feet above the level of the sea. The extensive view which we might have obtained from this elevated point, was almost entirely intercepted by the great masses of cloud, which hung upon the sides of the mountain, and admitted only partial and indistinct views of the landscape beneath. It has been said by Eghert Olafson, and others, that from one part of the channel which lies between Iceland and Greenland, the mountain of Snæfell Jokul may be seen on one side, and a lofty mountain in Greenland on the other. It is difficult to ascertain how far this is an accurate statement. The distance between the two countries at this place cannot be less than eighty or ninety leagues.

The clouds now began rapidly to accumulate, and were visibly rolling up the side of the mountain; we were therefore anxious to quit our present situation as speedily as possible, that we might repass the chasm before we were involved in mist. Our first object, however, was to examine the state of the magnetic needle, which Olafson in his travels asserts to be put into great agitation at the summit of this mountain, and no longer to retain its polarity. What may be the case a hundred feet higher, we cannot affirm; but at the point we reached, the needle was quite stationary, and, as far as we could judge, perfectly true. We then noted an observation of the thermometer, which we were surprised to find scarcely so low as the freezing point; and after an application to the brandy bottle, began with great care to retrace the footsteps of our ascent. We found re-crossing the chasm a work of no small danger; for whenever we stuck our poles into the snow bridge, they went directly through. The first person, therefore, who crossed, thrust his pole deep into the lower part of the wall, thus affording a point of support for the feet of those who followed; Mr. Holland, however, who was the second in passing over, had, notwithstanding, a narrow

escape, for his foot actually broke through the bridge of snow, and it was with difficulty he rescued himself from falling into the chasm beneath. We were scarcely all safe on the lower side of the chasm, when the mist surrounding us, made it extremely difficult to keep the tract by which we had ascended the mountain. When we came opposite to a small bank which we had remarked in our ascent as being free from snow, we desired our guide to remain where he was, that we might not lose the path, while we went to examine the spot. We found the bank to be almost entirely composed of fragments of pumice and volcanic scoriæ. After our return to the former tract, we made the best of our way back to Olafsvik, which we reached at about a quarter past six, to the great surprise of every one; for we were scarcely expected till the following morning; such is the reverential awe inspired by the Jokul. None of our party seemed more gratified with the exploit than our guide, who having always been accustomed to look upon the Jokul as some invincible giant, greatly exulted in this victory over him; but we afterwards learned, that he found considerable difficulty in making his friends credit his narrative of the ascent.

[*Sir George Mackenzie's Travels in Iceland.*]

CHAP. XIII.

ASIATIC VOLCANOES.

UPON the whole, this quarter of the world appears to have suffered less severely from the calamity of volcanoes and earthquakes than any other. Those that are chiefly worthy of notice are to be found in Japan and the New Hebrides.

SECTION I.

Volcanoes of Japan.

JAPAN is very remarkable for the great number of its burning mountains. Not far from Firanda, is a small rocky island, which hath been burning and trembling for many centuries;

and in another small island, opposite to Santzuma, is a volcano that has been burning at different intervals for many ages. On the summit of a mountain, in the province of Figo, is a large cavern, formerly the mouth of a volcano, but the flame has ceased, probably for want of combustible matter. In the same province, near a religious structure called the Temple of the Jealous God of Aso, a perpetual flame issues from the top of a mountain. In the province of Tsickusen is another burning mountain, where was formerly a coal-pit; but it being set on fire by the carelessness of the workmen, it has been burning ever since. Sometimes a black smoke, accompanied with a very disagreeable stench, is observed to issue out of the top of a famous mountain called Fesi, in the province of Seruga. This mountain is said to be nearly as high as the Peak of Teneriffe, but in shape and beauty is supposed to have no equal, and its top is covered with perpetual snow.

Captain Gore, when leaving the coast of Japan, passed by great quantities of pumice-stone, several pieces of which were taken up, and found to weigh from one ounce to three pounds; it was conjectured that these stones had been thrown into the sea by eruptions at various times, as many of them were covered with barnacles, and others were quite bare.

SECTION II.

Volcanoes of Kamtschatka.

THERE are three burning mountains in Kamtschatka which for many years have thrown out a considerable smoke, but do not often burst into flame. One of these is situated in the neighbourhood of Awatska; another called the volcano of Tolbatchiek, is situated on a neck of ground between the river Kamtschatka, and the Tolbatchiek. In the beginning of the year 1739, a whirlwind of flames issued from its crater, which reduced to ashes the forests on the neighbouring mountains: this was succeeded by a cloud of smoke which overspread and darkened the whole country, till it was dissipated by a shower of cinders, which covered the ground to the distance of thirty miles. The third volcano is on the top of the mountain of Kamtschatka, which is described as by far the highest in the peninsula; it rises from two rows of hills, somewhat in the form of a sugar-loaf, to a very great height; usually

throws out ashes twice or thrice a year, sometimes in such quantities, that for three hundred versts round the earth is covered with them: a conflagration began on the 25th of September, in the year 1737, and continued burning a week, with such violence, that the mountain appeared, to those who were fishing at sea, like one red-hot rock; and the flames that burst through several openings, with a dreadful noise, resembled rivers of fire. From the inside of the mountain were heard thunderings, crackings, and blowing like the blast of the strongest bellows, shaking all the neighbouring country; the nights were most terrible; but at last the conflagration ended, by the mountain's casting out a prodigious quantity of cinders and ashes, among which were porous stones, and glass of various colours. When Captain Clerk sailed out of the harbours of Saints Peter and Paul, to the northward, an eruption of the first of these volcanoes was observed, being on the 15th of June, 1778; before day-light a rumbling noise was heard, resembling distant hollow thunder; and when the day broke, the decks and sides of the ships were seen to be covered with a fine dust like emery, near an inch thick, the air at the same time continued loaded and darkened with this substance, and towards the mountain, which is situated to the north of the harbour, was so thick and black, that the body of the hill could not be distinguished. About twelve o'clock, and during the afternoon, the explosions became louder, and were followed by showers of cinders, which were in general about the size of peas, though many were picked up upon the deck larger than a hazel nut. Along with the cinders fell several small stones, which had undergone no change from the action of fire. In the evening, dreadful thunder and lightning came on, which, with the darkness of the atmosphere, and the sulphureous smell of the air, produced altogether a most awful effect. The ships were at that time about eight leagues from the foot of the mountain. Capt. Clerke was informed, on his return, that at the craters of St. Peter and of St. Paul stones were thrown forth of the size of a goose's egg.

SECTION III.

Volcanoes of the New Hebrides.

A cluster of islands in the Pacific Ocean, which was first traced by Quiros, in 1606, next by M. de Bougainville, in 1768, and after-

TRUNCATED MOUNTAIN, WITH THE FOCUS OF AN EXTINGUISHED VOLCANO,

in the Island of Owyee.

ward by Captain Cook, the first of whom called what he had discovered Sierra del Esperitu Santo; the next, the Archipelago of the Great Cyclades; and the last, who visited each island, the New Hebrides, are situated between the latitudes of 40° 29′ and 20° 4′ south, and between 166° 41′ and 170° 21′ east longitude; they are eighteen in number, and extend one hundred and twenty-five leagues in the direction of north, north-west, and south-south-east. On one of the islands, which is named Tanna, a volcano was seen from Captain Cook's ship, about four miles to the westward, which was burning with great fury. In the night of the 5th of August, 1774, it vomited vast quantities of fire and smoke, and the flames were seen to rise above the hills which lay between it and the ship. At every eruption it made a loud rumbling noise, like that of thunder, or the blowing-up of large mines. A heavy shower of rain, which fell at the same time, seemed to increase it; and the wind blowing from that quarter, the air was loaded with its ashes, which fell so thick, that every thing was covered with the dust. It was a kind of fine sand or stone, ground or burnt to powder, and was exceedingly troublesome to the eyes.

[*Cook. Quiros. Bougainville. Forster.*]

CHAP. XIV.

VOLCANOES OF THE AFRICAN ISLANDS.

THE continent of Africa appears, as far as we are acquainted with it, to have been but little afflicted with volcanic visitations at any time. But its different groupes of islands exhibit strong and striking marks of this terrible scourge. These are chiefly to be traced in St. Helena, among the Cape Verd and Fortunate Islands, or Canaries, and in the Isle of Bourbon or Reunion: to which we shall confine our attention.

SECTION I.

Volcanoes of St. Helena.

BESIDES the volcanoes which are still burning, there are innumerable mountains which bear evident marks of fire that is now extinct, and has been so from the time of the earliest traditions: among these is the isolated rock of St. Helena, where the inequalities of surface are manifestly the effect of the sinking of the earth; for the opposite ridges, though always separated by deep, and sometimes by broad vallies, are exactly similar, both in appearance and direction: and that the sinking of the earth in those parts was caused by subterraneous fires, is equally manifest from the stones; for some of them, especially those in the bottom of the vallies, are burnt almost to a cinder; in some there are small bubbles, like those that are seen in glass which has been urged almost to fusion; and some, though at first sight they do not appear to have been exposed to the action of great heat, will be found, upon a closer inspection, to contain small pieces of extraneous bodies, as, particularly, mundick, which have yielded to the power of fire, though it was not sufficient to alter the appearance of the stone which contained them.

SECTION II.

Volcanoes of the Cape Verd Islands.

THIS group of islands afford several that have been long extinct. Among those that are occasionally active, the chief is to be found in the island of Fogo or Fuego. This is situated in latitude 15° 20′ north, is much higher than any of the rest, and appears at sea like one continued mountain. In sailing by it, no valleys are to be seen, these only resembling gutters, made by torrents of rain running down the mountain: but when a person is on shore, near one of these seeming gutters, he finds that they are deep vallies bounded by lofty mountains.

On the top is a volcano, which may be seen at a great distance at sea. It sometimes casts forth fragments of rock, of an amazing size, to a vast height, with a noise like that of the loudest thunder; and sometimes torrents of flaming brimstone pour from the peak, like

bitants can gather what quantities of that mineral substance they please. It is not unlike common brimstone, but is of a much brighter colour, and on being burnt, gives a clearer flame. At other times, the volcano casts forth such an amazing quantity of ashes, that the adjacent parts are covered, and many goats smothered.

SECTION III.

Volcanoes of the Canaries.

THE principal volcanoes belonging to this group of islands are to be met with in Lancerota, Fuertaventura, Palma, and Teneriffe.

In Lancerota and Fuertaventura, are many hills that were formerly volcanoes, the tops of which are of a small circumference, and are hollow for a little way downward; the edges of the tops being usually narrow and sharp, and on the outside is generally seen a great deal of black dust, and burnt stone, like pumice-stone, only darker and more ponderous. No eruptions have been known to happen for several ages, except one at Lancerota, which, about sixty years ago, broke out on the south-west part of the island, throwing out such an immense quantity of ashes and huge stones, and with so dreadful a noise, that many of the inhabitants, leaving their houses, fled to Fuertaventura; but some time after, finding that those who ventured to stay had received no hurt, they took courage, and returned. This volcano was near the sea, in a place remote from any habitation. At a small distance from it, a pillar of smoke issued from the sea, and afterwards a small pyramidical rock arose, which still continues. This rock was joined to the island by the matter thrown out of the volcano. The noise of the eruption was so loud, that it was heard at Teneriffe, although at the distance of forty leagues, which was probably occasioned by the wind generally blowing from Lancerota toward that island.

PALMA is a high and spacious mountain, steep on all sides. It is called *La Caldera*, or *the Cauldron*, from a hollow like that on the Peak of Teneriffe. The summit is about two leagues in circumference, from which, on the inside, the Cauldron descends gradually to the bottom, which is a space of about thirty acres. On the declivity of the inside spring several rivulets, which, joining together at the bottom, issue in one stream through a passage to the outside

of the mountain from which this brook descends, and having run some distance, turns two sugar mills. The water of this stream is unwholesome, on account of its mixing with other water of a pernicious quality in the Cauldron, all the inside of which abounds with herbage, and is covered with palms, pitch-pine, laurel, lignum-rhodium, and ratamas, which last have in this island a yellow bark, and grow to the size of large trees, but in the others they are only shrubs. The people here take great care not to let the he-goats feed on the leaves of the ratama, as they imagine those leaves breed a stone in the bladder, which kills the animal.

TENERIF, or the *White Mountain*, derives its name from the inhabitants of the neighbouring island of Palma, among whom *thener*, we are told by Glas, imports a mountain, and *if*, white, its peak or summit being always covered with snow. On the north-west side of the island is a bay called *Adexe*, or rather *Adeke*, where large ships may anchor: and on its north-west side is a haven called Garrachica, once the best port in the island, but destroyed by a tremendous earthquake in 1704, which the natives have significantly denominated the "earthquake-year." The harbour was filled-up by the river of burning lava that flowed into it from the volcano, so that houses are now built where ships formerly lay at anchor; though vessels may safely approach the coast in the summer.

The earthquake began on December 24 of the above year, and in the space of three hours not less than twenty-nine shocks were felt. They still, however, increased in violence, so as at length to rock all the houses, and oblige the inhabitants to abandon them. The consternation became universal; and the people, with the bishop at their head, made processions and prayers in the open fields. On the 31st, a great light was observed at Manja, towards the White Mountains, when the earth opening, two volcanoes were formed that threw up such heaps of stones, as to raise two considerable mountains. On the 5th of January the sun was totally obscured with clouds of smoke and flame, which continually increasing, augmented the consternation and terror of the inhabitants. Before night, the whole country, for nine miles round, was in flames, by the flowing of the liquid fire with the rapidity of a current, into all quarters, from another volcano, which opened by at least thirty different vents within the compass of half a mile. The horror of this the rushing of water down a steep mountain; after which the inha-

scene was greatly increased by the violence of the shocks, which never once remitted, but by their force entirely overthrew several houses, and shook others to their very foundations; while the wretched inhabitants were again driven, defenceless and dismayed, into the open fields, where they every moment expected to be swallowed-up by some new gulph. The noise of the volcanoes was heard at the distance of twenty leagues, and even there the sea shook with such violence as alarmed the mariners, who apprehended that the ship had struck upon a rock. Meanwhile, a torrent of sulphur and melted ores of different kinds rushed from this last volcano toward Guimar, where the houses and public buildings were thrown down by the violence of the accompanying shocks. On the 2d of February another volcano broke out, even in the town of Guimar, which swallowed up a large church. From the 24th of December to the 23d of February, the people were constantly alarmed by continual shocks of earthquakes, and the terrible volcanoes that burst forth in different parts of the island. Since that time no earthquake or eruption has happened, but smoke continually issues from near the top of the mountain.

It is in the centre of Teneriffe, whose form is nearly triangular, each side about twelve leagues long, that we meet with the celebrated *pike* or *peak*, called *Teyde* by the ancient inhabitants, a name which it retains to the present day. There are three valuable accounts of journies made to the top of the peak by English travellers: that of Dr. Spratt, Bishop of Rochester; that of Dr. Heberden, both contained in the Philosophical Transactions; and that of Mr. Glas, who ascended it about nine years after Dr. Heberden, and has given a minute description of his tour in his History of the Canary Islands. The substance of these different accounts shall be laid before the reader.

In the beginning of the month of September 1761, at about four in the afternoon, Mr. Glas set out on horseback, in company with the master of a ship, to visit the peak. They had with them a servant, a muleteer, and a guide; and, after ascending about six miles, arrived toward sun-set at the most distant habitation from the sea, which is in a hollow: here finding an aqueduct of open troughs, that convey water down from the head of the hollow, their servants watered the cattle, and filled some small barrels to serve them in their

expedition. The gentlemen here alighted, and walking into the hollow, found it very pleasant, abounding with many trees that sent forth an odoriferous smell; and near the houses were some fields of maize, or Indian corn.

Mounting again, they travelled for some time up a steep road, and reached the woods and clouds just as it grew dark. They could not miss their way, the road being bounded on both sides with trees or bushes, which were chiefly laurel, savine, and brush-wood. Having travelled about a mile, they came to the upper edge of the wood, above the clouds, where alighting, they made a fire, and supped; soon after which they lay down to sleep under the bushes.

About half an hour after ten, the moon shining bright, they mounted again, travelling slowly two hours, through an exceeding bad road, resembling the ruins of stone buildings, scattered over the fields. After they had got out of this road, they came upon small light pumice-stone, like shingle; upon which they rode at a pretty good pace for near an hour. The air now began to be very sharp, cold, and piercing. Their guide advised them to alight here, as the place was convenient, and rest till four or five in the morning. To this they agreed, and entered a cave, the mouth of which was built up to about a man's height, to exclude the cold. Here they found some dry withered retamas, which was the only shrub or vegetable; with these they made a great fire, and then fell asleep; but were soon awaked by an itching occasioned by a cold thin air, want of comfortable lodgment, and sleeping in their cloaths; but although they lay so near the fire that one side was almost scorched, yet the other was benumbed with cold.

At about five in the morning they mounted again, and travelled slowly about a mile; for the road was rather too steep for travelling quick on horseback, and their beasts were become fatigued. At last they came among some great loose rocks, where was a kind of cottage built of loose stones, called La Estantia de los Ingleses, or the English baiting-place, probably from some of the English resting here on their way to visit the peak; for none take that journey but foreigners, and some poor people who earn their bread by gathering brimstone. Here they again alighted, the remainder of their way being too steep for riding, and left the servant to look after the horses, while they proceeded on their journey. They walked hard

to get themselves a heat, but were soon fatigued by the steepness of the road, which was loose and sandy. On their reaching the top of this hill, they came to a prodigious number of large and loose rocks or stones, whose surfaces were flat, and each of them on a medium about ten feet every way. This road was less steep than the other; but they were obliged to make many circuits to avoid the rocks.

Here is the famous cave of Teyde, which is surrounded, or rather buried, on all sides by large volcanic rocks, which the Spaniards call *mal-payses*. The cave is about fifteen feet wide at the entrance, but its extremity, Dr. Heberden says, he could not discover. Here too is the grand reservoir of snow, whence these islanders are supplied, when their common reservoirs, which furnish snow for cooling their liquors, fail them. Mr. Glas and his company entered it. They found the water so excessively cold that it could not be drunk. After travelling about a quarter or half a mile upon the great stones, they reached the bottom of the real peak or sugar-loaf, which is exceeding steep, and the difficulty of ascending was increased, and rendered more fatiguing, by the ground being loose, and giving way under their feet; for though this eminence is not above half a mile in height, they were obliged to stop and take breath near thirty times; and when they at last reached the top, being quite spent with fatigue, they lay about a quarter of an hour to rest themselves and recover their breath.

When they left the English pitching-place in the morning, the sun was just emerging from the clouds, which were spread under them, at a great distance below, and appeared like the ocean. Dr. Heberden says, " a sea of ash-coloured clouds appeared below." Above the clouds, at a vast distance to the north, they perceived something black, which they imagined to be the top of the island of Madeira, and taking the bearings of it by a pocket compass, found it to be exactly in the direction of that island from Teneriffe; but before they reached to the top of the peak it disappeared. From this spot they saw the top of the islands of Gran Canaria, Hiero, Palma, and Gomera, which seemed to be quite near, but could neither perceive Lancerota nor Fuertaventura, they being not high enough to pierce the clouds.

The top of the peak is about an hundred and forty yards in length,

and an hundred and ten in breadth. It is hollow, and shaped like a bell with the mouth upward, says Mr. Glas. Dr. Heberden describes it as resembling a truncated cone with its base uppermost. These two travellers differ widely as to the depth of the crater, which the natives call caldera, the first calling it forty yards to the bottom, the latter saying it is about twelve or fifteen feet deep. This caldera or cauldron is nearly circular, its diameter about forty fathom. The ground is very hot, and from near twenty spiracula, as from so many chimnies, a smoke or vapour arises, which is of a strong sulphureous smell. The whole soil seemed mixed or powdered with brimstone, which formed a beautifully-coloured surface. There is one of the rocks which forms a kind of vault or niche, against which the vapours condensing, produce what the inhabitants call *azufre de gota*, or drop-brimstone. On observing some spots of earth, or soft clay, Mr. Glas's company tried the heat with their fingers, but could not thrust them in farther than half an inch, for the deeper they penetrated the hotter they felt it. They then took their guide's staff, and thrust it about three inches deep into a hole or porous substance, where the smoke seemed thickest, and having held it there about a minute, drew it out, and found it burned to charcoal.

From this spot the clouds beneath them, which were at a great distance, made a very extraordinary appearance: they seemed like the ocean, only the surface was not quite so blue and smooth, but had the resemblance of white wool; and where this cloudy ocean, as it may be called, touched the mountain, it seemed to foam like billows breaking on the shore. When they ascended through the clouds it was dark; but when they afterward mounted again, between ten and eleven o'clock, and the moon shone bright, the clouds were then below them, and about a mile distant. They then mistook them for the ocean, and wondered to see it so near, nor did they discover their mistake till the sun arose. When in descending from the peak, they passed through the clouds, they appeared as a thick fog or mist, resembling those frequently seen in England: all the trees of the wood, and their clothes were wet with them.

On the top of the peak the air was thin, cold, and piercing, like the south-easterly winds felt in the great desert of Africa. In ascending the sugar-loaf, which is very steep, and covered with snow the

greatest part of the year, their hearts panted and beat violently, and, as hath been already observed, they were obliged to rest about thirty times to take breath; and this was probably as much owing to the thinness of the air causing a difficulty of respiration, as to the uncommon fatigue they suffered in climbing the hill. Their guide, who was a thin, active old man, was far from being affected in the same manner, but climbed up with ease like a goat; for he was one of the poor men who earn their living by gathering brimstone in the cauldron, and other volcanoes, the peak itself being no other, though it has not burned for some years; for the sugar-loaf is entirely composed of earth mixed with ashes and calcined stones, thrown from the bowels of the earth, and the great square stones before described were probably thrown, in some eruption, out of the cauldron, or hollow of the peak, when it was a volcano.

Having surveyed every thing worthy of notice, they descended to the place where they had left their horses, which took them up only half an hour, though they were about two hours and a half in ascending. It was then about ten in the morning, and the sun shone so exceedingly hot, that they were obliged to take shelter in the cottage, and, being extremely fatigued, laid themselves down to sleep; but the cold was so intense in the shade, that they could not close their eyes, and they were obliged to kindle a fire to render their situation supportable.

They were then enabled to take some repose; after which they mounted their horses about noon, and descending by the same way they went up, came to some pines, situated about two miles above the clouds. Between these pines and the peak no herb, shrub, tree, or grass can grow, except the before-mentioned ratamas. At about five in the evening they arrived at Oratava, not having alighted by the way to stop, only sometimes to walk where the road was too steep for riding.

It should seem that Mr. Glas made his journey up the mountain rather too late in the season; for Mr. Anderson, who was surgeon on board the Resolution, in Captain Cook's third voyage round the world, was assured, when here, that no person can live comfortably within a mile of the perpendicular height of the peak after the month of August. Dr. Heberden made his journey in the month of February.

The whole distance they rode in the five hours spent in coming

down from the English pitching-place to Orotava, they computed to be about fifteen English miles, travelling at the rate of about three miles an hour. Mr. Glas supposes the perpendicular height of the English pitching-place to be about four English miles, and adding to that a mile of perpendicular height from it to the peak, observes, that the whole will be about five English miles, and that he is very certain he cannot be mistaken in this calculation above a mile either way; but this is merely conjectural, being founded on no solid data. Dr. Heberden, who was provided with proper instruments to ascertain its height, and has made the nicest observations at three different times, found it to be 2566 fathoms, or 15,396 English feet, above the level of the sea, which is only 148 yards less than three miles, reckoning the mile at 1760 yards; but the Chevalier de Borda, who measured the height of this mountain in the year 1776, makes it to be only 1931 toises, or 12340 English feet. Capt. Cook, in his first voyage, describes the appearance of this mountain, when viewed from the sea at sun-set, as very striking; for when the sun was below the horizon, and the rest of the island appeared of a deep black, the mountain still reflected his rays, and glowed with a warmth of colour which no painting can express. Mr. William Anderson, already mentioned, says of the peak of Teneriffe, "It is certainly far from equalling the noble figure of Pico, one of the Western Islands, though its perpendicular height may be greater. This circumstance perhaps arises from its being surrounded by other high hills, whereas Pico stands without a rival.

Though the body of the mountain is covered with clouds, the peak is generally seen above them, quite clear, but sometimes the contrary happens, the whole body of the mountain being without a cloud, and only the summit of the peak covered with a thick white cloud, as with a cap. "This," says Dr. Heberden, "is often observed in the finest weather, and the Spaniards, on this occasion, say, "*El pico tiene su sombrerillo puesto.* The peak has put his little hat on;" and they look on it as a certain sign of rain. The doctor says farther, that during the six or seven years that he lived in the villa of Orotava, where he had a continual sight of the peak, he never remembered one instance in which the prediction of rain failed. When Sir Joseph Banks visited this island, the doctor presented him with some salt, which he collected at the top of the mountain, which he supposes to be the true natrum, or nitrum, of the ancients.

SECTION IV.

Volcanoes of the Isle of Bourbon.

THE face of the Isle of BOURBON or REUNION is peculiarly volcanic, and studded with masses of basaltic columns, of various forms and directions. M. Bory has given an interesting and picturesque description of these, in his "Voyage dans les quatres principales Isles des Mers d'Afrique," printed at Paris 1804, in 3 vols. 8vo. The principal summit of the volcano is allowed to retain the appellation of *Mascarenhas*, after the name of the Portuguese admiral by whom the island was first discovered. "The small hill," says M. Bory, "at the basis of which we were now arrived, after so much fatigue, is about a hundred and sixty feet in height. It did not appear to us truncated, and we soon climbed it, though the sides be very steep, so as to form with the horizon an angle of more than eighty degrees. They are composed of little currents of glassy scoriæ, spongy, very light and brittle, and exteriorly of a brown colour, with metallic or red reflections from the pores. This volcanic substance is easily broken with the fingers, and reduced to brilliant dust, which resembles aventurine. From the top of the Piton we perceived, on the right and the left, parts of the circumference of two immense craters, which induced us to call this the central hill. The access of this central hill is nearly perpendicular; and on the summit is a round hole about forty fathoms in diameter, and eighty feet in depth. The bottom of this crater was filled with fragments of greyish lava, piled without any order, while the sides were very thin and much scorified on the outside; and were not covered with any sort of varnish, nor with that lava in tears or drops, which in general clothe the other vents. They are formed of confused fragments of different hard and grey lavas, compact, or porous. From some rents there arose light vapours, leaving yellow traces of sublimated sulphur, on the spots exposed to their contact. At one place, where a projecting rock formed a cornice, stopping for a while one of these cords of vapour, it was dissolved in drops of water to a considerable quantity.

"In general a very false idea is formed of volcanoes, and many works which pretend to describe them, paint them very different from what they are. If we believe many travellers, on the brink of a

Clavigero makes more than half a mile wide; but though active formerly, it has not emitted flames of late. In the last century, however, it still continued to emit flames and ashes, the last of which overspread the country to a considerable extent. Iztaccihuatl appears to have been exhausted for a longer period than the preceding. Both these mountains, like Orizava, have their summits covered with perpetual snow, in such quantities as to supply the metropolis and the adjacent country for forty miles round, as an article of luxury to the wealthy.

All the others we have enumerated have been quiescent, perhaps immemorially, except Jorullo, which is the most singular of the whole; and whose history, therefore, we shall give more at large from the very interesting account of it, lately published by M. Humboldt.

"The grand catastrophe," says he, "in which this volcanic mountain issued from the earth, and by which the face of a considerable extent of ground was totally altered, was perhaps one of the most extensive physical changes, that the history of our globe exhibits. Geology points out spots in the ocean, where, within the last two years, volcanic islets have arisen above the surface of the sea, as near the Azores, in the Archipelago, and on the south of Iceland: but it records no instance of a mountain of scoriæ and ashes, 517 met. [563 yards] above the old level of the neighbouring plains, suddenly formed in the centre of a thousand small burning cones, thirty-six leagues from the shore, and forty-two leagues from any other volcano. This phænomenon remained unknown to the mineralogists and natural philosophers of Europe, though it took place but fifty years ago, and within six days journey of the capital of Mexico.

"Decending from the central flat towards the coasts of the Pacific ocean, a vast plain extends from the hills of Aguasarco to the villages of Toipa, and Patatlan, equally celebrated for their fine cotton plantations. Between the picachos del Mortero and the cerras de las Cuevas and de Cuiche, this plain is only from 750 to 800 met. [820 to 880 yards] above the level of the sea. Basaltic hills rise in the midst of a country, in which porphyry with base of green-stone predominates. Their summits are crowned with oaks always in verdure, and the foliage of laurels and olives intermingled with dwarf fan palms. This beautiful vegetation forms a singular contrast with the arid plain, which has been laid waste by volcanic fire.

To the middle of the eighteenth century fields of sugar-canes and indigo extended between two rivulets, called Cuitimba and San Pedro. They were skirted by basaltic mountains, the structure of which seems to indicate, that all the country, in remote periods, has several times experienced the violent action of volcanoes. These fields, irrigated by art, belonged to the estate of San Pedro de Jorullo, or Xorullo, one of the largest and most valuable in the country. In the month of June, 1759, fearful rumbling noises were accompanied with frequent shocks of an earthquake, which succeeded each other at intervals for fifty or sixty days, and threw the inhabitants of the estate into the greatest consternation. From the beginning of the month of September, every thing seemed perfectly quiet, when in the night of the 28th of that month a terrible subterranean noise was heard anew. The frightened Indians fled to the mountains of Aguasarco. A space of three or four square miles, known by the name of Malpays, rose in the shape of a bladder. The boundaries of this rising are still distinguishable in the ruptured strata. The Malpays towards the edge is only 12 met. [13 yards] above the former level of the plain, called las playas de Jorullo; but the convexity of the ground increases progressively towards the centre, till it reaches the height of 160 met. [175 yards.]

They who witnessed this grand catastrophe from the top of Aguasarco assert, that they saw flames issue out of the ground for the space of more than half a league square; that fragments of red hot rocks were thrown to a prodigious height; and that through a thick cloud of ashes, illumined by the volcanic fire, and resembling a stormy sea, the softened crust of the earth was seen to swell up. The rivers of Cuitimba and San Pedro then precipitated themselves into the burning crevices. The decomposition of the water contributed to reanimate the flames, which were perceptible at the city of Pascuoro, though standing on a very wide plain 1400 met. [1530 yards] above the level of the playas de Jorullo. Eruptions of mud, particularly of the strata of clay including decomposed nodules of basaltes with concentric layers, seem to prove, that subterranean waters had no small part in this extraordinary revolution. Thousands of small cones, only two or three yards high, which the Indians call ovens, issued from the raised dome of the Malpays. Though the heat of these volcanic ovens has diminished greatly within these

fifteen years, according to the testimony of the Indians, I found the thermometer rise to 95° [if centig. 203° F.] in the crevices that emitted an aqueous vapour. Each little cone is a chimney, from which a thick smoke rises to the height of ten or fifteen met. [11 or 16 yards]. In several a subterranean noise is heard like that of some fluid boiling at no great depth.

Amid these ovens, in a fissure, the direction of which is from N. N. E. to S. S. E., six large hummocks rise 400 or 500 met. [440 or 550 yards] above the old level of the plain. This is the phenomenon of Monte Novo at Naples repeated several times in a row of volcanic hills. The loftiest of these huge hummocks, which reminded me of the district of Auvergne, is the large volcano of Jorullo. It is constantly burning, and has thrown out on the north side an immense quantity of scorified and basaltic lava, including fragments of primitive rocks. These grand eruptions of the central volcano continued till February 1760. In the succeeding years they became gradually less frequent. The Indians, alarmed by the horrible noise of the new volcano, at first deserted the villages for seven or eight leagues round the plain of Jorullo. In a few months they became familiar with the alarming sight, returned to their huts, and went down to the mountains of Aguasarco and Santa Ines, to admire the sheaves of fire thrown out by an infinite number of large and small volcanic openings. The ashes then covered the houses of Queretoro, more than 48 leagues [120 miles] in a right line from the place of the explosion. Though the subterranean fire appears to be in no great activity * at present, and the Malpays and the great volcano begin to be covered with vegetables, we found the air so heated by the little ovens, that in the shade, and at a considerable distance from the ground, the thermometer rose to 43° (109·4°F). This fact evinces, that there is no exaggeration in the report of some of the old Indians, who say, that the plains of Jorullo were uninhabitable for several years, and even to a considerable distance from the ground raised up, on account of the excessive heat.

---

* In the bottom of the crater we found the heat of the air 47° [116·6°F.] and in some places 58° and 60° [136·4° and 140°]. We had to pass over cracks exhaling sulphurous vapours, in which the thermometer rose to 85° [185°]. From these cracks, and the heaps of scoriæ that cover considerable hollows, the descent into the crater is not without danger.

Near the cerro of Santa Ines the traveller is still shewn the channels of Cuitimba and San Pedro, the limpid waters of which formerly refreshed the sugar-canes on the estate of Don Andrew Pimental. These springs were lost in the night of the 29th of September, 1759: but 2000 met. (near 2200 yards) to the westward, in the soil that has been elevated, two rivulets are seen to break out of the clayey dome of the furnaces, exhibiting themselves as thermal waters, in which the thermometer rises to 52·7° (126·86°F.) The Indians still give these the names of San Pedro and Cuitimba, because in several parts of the Malpays large bodies of water are supposed to be heard running from east to west, from the mountains of Santa Ines to the estate of the Presentation. Near this estate is a brook that emits sulphuretted hydrogen gas: it is more than 7 met. (near 8 yards) wide, and is the most copious hidrosulphurous spring I ever saw.

In the opinion of the natives these extraordinary changes I have described, the crust of earth raised and cracked by volcanic fire, the mountains of scoriæ and ashes heaped up, are the works of monks; the greatest, no doubt, they ever produced in either hemisphere. Our Indian host, at the hut we inhabited in the plain of Jorullo, told us, that some missionary capuchins preached at the estate of San Pedro, and, not meeting a favourable reception, uttered the most horrible and complicated imprecations against this plain, then so beautiful and fertile. They prophesied, that the estate should first be swallowed up by flames issuing out of the bowels of the earth; and that the air should afterward be cooled to such a degree, that the neighbouring mountains should remain for ever covered with ice and snow. The first of these maledictions having been so fatally verified, the common people foresee in the gradual cooling of the volcano the presage of a perpetual winter. I have thought it right to mention this vulgar tradition, worthy a place in the epic poem of the jesuit Landivar, because it exhibits a striking feature of the manners and prejudices of these remote countries. It shews the active industry of a class of men, who, too frequently abusing the credulity of the people, and pretending to possess the power of suspending the immutable laws of nature, know how to avail themselves of every event for establishing their empire by the fear of physical evil.

The situation of the new volcano of Jorullo leads to a very cu-

rious geological observation. It is well known to geographers, that there is in New Spain a line of great heights, or a narrow zone included between the latitudes of 18° 59′ and 19° 12′, in which are all the summits of Anahuac that rise above the region of perpetual snow. These summits are either volcanoes still actually burning; or mountains, the form of which, as well as the nature of their rocks, renders it extremely probable, that they formerly contained subterranean fire. Setting out from the coast of the Gulf of Mexico, and proceeding westward, we find the peak of Oribaza, the two volcanoes of la Puebla, the Nevado de Teluca, the peak of Tancitaro, and the volcano of Colima. These great heights, instead of forming the ridge of the cordillera of Anahuac, and following its direction, which is from S. E. to N. W. are on the contrary in a line perpendicular to the axis of the great chain of mountains. It is certainly worthy of remark, that in the year 1759 the new volcano of Jorullo was formed in the continuation of this line, and on the same parallel as the ancient Mexican volcanoes.

A view of my plan of the environs of Jorullo will shew, that the six large hummocks have risen out of the earth on a vein that crosses the plain from the cerro of las Cuevas to the pichaco del Montero. The new mouths of Vesuvius too are found ranged along a fissure. Do not these analogies give us reason to suppose, that there exists in this part of Mexico, at a great depth within the earth, a fissure stretching from east to west through a space of 137 leagues [343 miles], and through which the volcanic fire has made its way at different times, bursting the outer crust of porphyritic rocks, from the coast of the Gulf of Mexico to the South Sea? Is this fissure prolonged to that little group of islands, called by Colluet the Archipelago of Regigedo, and round which, in the same parallel with the Mexican volcanoes, pumice-stone has been seen floating? Naturalists who distinguish the facts offered by descriptive mineralogy from theoretical reveries concerning the primitive state of our planet, will pardon me for having consigned these observations to the general map of New Spain, contained in the Mexican Atlas.

[*Humboldt, as above.*]

SECTION II.

Volcanoes of New Grenada.

These are chiefly to be met with on the summits of the enormous mountains in the viceroyalty of New Grenada, and in the neighbourhood of the city of Quito. These mountains constitute some of the grandest objects in natural geography, being many of them the loftiest on the face of the globe, while their volcanoes are of a most sublime and horrible character. The most celebrated of these elevated excavations are, Chimborazo, Cotopoxi, Sangai, Pichincha, and Antisanas; most of them, however, have expended themselves, except Sangai and Cotopoxi.

Chimborazo, the loftiest of the whole, about a hundred English miles to the south of Quito, and about ten to the north of Riobamba, is computed by Bouguer to be 3217 French toises, or 20,280 feet above the level of the sea; and consequently to be about 5,000 feet, or one quarter higher than Mount Blanc: its region of perpetual snow extends to about 2,400 feet from the summit.

The next loftiest mountain is Cotopaxi, estimated at about 18,500 feet, and situated at about twenty-five miles to the south-east of Quito. Pichincha, lies still nearer to the capital, but in a south-westerly direction; and Altar and Sangai to the south-east.

This last is a páramo *, or vast desert, the summit always covered with snow. It is a perpetual volcano, whose fire is continually seen, and whose explosions are heard at a distance of forty leagues. The adjacent country is entirely barren, in consequence of being covered with the cinders ejected from its mouth. In this mountain rises the river Scagui, which being joined by the Upano, forms the Payra, a large river, which discharges itself into the river Maranon, or river of Amazons.

Cotopoxi is supposed to have become a volcano about the time when the Spaniards first invaded the country; and Ulloa asserts that it ejected stones of eight or nine feet in diameter, to a distance of more than nine miles. A new eruption occurred in 1743, which had been for some days preceded by a continual interior rumbling

* A Spanish term contracted from *par eremo*, eremitical, hermetical, hermit-like, solitary.—*Editor.*

noise; after which an aperture was made in its summit, as also three others near the middle of its declivity; which parts, when the eruption commenced, were buried under prodigious masses of snow. The ignited substances which were ejected, being mingled with a considerable quantity of snow and ice, melting amidst the flames, were carried down with such amazing rapidity, that the plain from Callo to Latacunga was overflowed, and all the houses, with their wretched inhabitants, were swept away in one general and instantaneous destruction. The river of Latacunga was the receptacle of this dreadful flood, till becoming swollen above its banks, the torrent rolled over the adjacent country, continuing to sweep away houses and cattle, and rendered the land near the town of the same name as the river, one vast lake. Here, however, the inhabitants had sufficient warning to save their lives by flight, and retreated to a more elevated spot at some distance. During three days the volcano ejected cinders, while torrents of lava, with melted ice and snow, poured down the sides of the mountain. The eruption continued for several days longer, accompanied with terrible roarings of the wind, rushing through the craters which had been opened. At length all was quiet, and neither smoke nor fire was to be seen; until, in May, 1744, the flames forced a passage through several other parts on the sides of the mountain; so that in clear nights, the flames, being reflected by the transparent ice, exhibited a very grand and beautiful illumination. On November 13th following, it emitted such prodigious quantities of fire and lava that an inundation equal to the former soon ensued; and the inhabitants of the town of Latacunga, for some time, thought their ruin irremediable. The roarings of the volcano are said by Humboldt to have been heard at *two hundred and twenty leagues* distance.

Nothing, however, can equal the fertility, pure, etherial atmosphere, and picturesque beauty of the sides of the mountain, which have generally been described as a terrestrial paradise; in consequence of which alone the inhabitants still adhere to this stupendous region, and dare the dangers of its eruptions and earthquakes.

The most horrible visitation of this double kind to which they have been exposed, occurred on February 4, 1797, about eight o'clock in the morning. At Quito little damage was sustained, but the subterranean thunder, and the shocks repeated every six hours, occasioned indescribable horror and dismay. On the day ensuing,

it was known, towards the evening, that Latacunga, and all the hamlets in its corregiamento, were utterly destroyed, not one stone remaining upon another. Multitudes of persons perished, and the stench of the dead bodies infected the survivors. Various mountains split near Ambulo, and by their sudden fall produced still greater destruction among the human race. Quero, with all its people, was buried in an instant by a cliff which fell on the town. Pelileo was overwhelmed by a stream of water and mud ; the circumjacent lands were all transposed ; and a deadly silence betrayed the general ruin. The elegant town of Riobamba became a heap of wreck and desolation, and shortly afterwards totally disappeared : for the peak of Sicalpa falling on the town, and damming up the two rivers that pass by it, formed a lake, so that even the ruins of the town were not visible. Of nine thousand inhabitants, only about four hundred escaped. Alansi and Guaranda also suffered extremely. The fate of Cuenca, Leja, Jaen, and Guayaquil, was at that time unknown ; but the shocks do not appear to have extended so far. The adjoining volcano Tungarunga seems to have united in the fury ; as extensive subterranean thunders proceeded from this last quarter, and the most fearful mischief was in its vicinity. Towards the north the earthquake was faintly perceived at Pasto.

We cannot give a better account of what may be called the present state of the country than in the following words of M. Humboldt, who has visited it since the above devastation.

We arrived at Quito, by crossing the snows of Quiridien and Tolima, for as the cordillera of the Andes forms three separate branches, and at Santa Fe de Bogoto, we were on the easternmost, it was necessary for us to pass the loftiest, in order to reach the coast of the Pacific ocean. We travelled on foot, and spent seventeen days in these deserts, in which are to be found no traces of their ever having been inhabited. We slept in huts made of the leaves of the heliconia, which we carried with us for the purpose. Descending the Andes to the west, there are marshes, in which you sink up to the knees. The latter part of the time we were deluged with rain ; our boots rotted on our legs ; and we arrived barefoot at Carthago, but enriched with a fine collection of new plants, of which I have a great number of drawings.

From Carthago we went to Popayan, by way of Buga, crossing the beautiful vale of the river Cauca, and having constantly

at one side the mountain of Choca, in which are the mines of Platina.

We staid during the month of November 1801, at Popayan, visiting the Basaltic mountains of Julusuito; the mouths of the volcano of Purace, which evolve, with a dreadful noise, vapours of hydrosulphurated water; and the porphyritic granites of Pische, which form columns of five, six, or seven sides, similar to those I remember I saw in the Euganean mountains in Italy, which Strange has described.

In travelling from Popayan to Quito, we had to cross the *paramos* of Pasto, and this in the rainy season. Every place in the Andes, where, at the height of 3500 or 4000 yards, vegetation ceases, and the cold penetrates to the very marrow of your bones, is called a *paramo*. To avoid the heats of the valley of Patia, where, in a single night, a fever may be caught, that will last three or four months, we passed the summit of the Cordillera, traversing frightful precipices.

We spent our Christmas at Pasto, a little town at the foot of a tremendous volcano, where we were entertained with great hospitality. The roads leading to and from it are the most shocking in the world. Thick forests, between marshes, in which the mules sink up to their bellies; and gullies so deep and narrow, that we seemed entering the galleries of a mine.

The whole province of Pasto, including the environs of Guachucal and Tuqueres, is a frozen plain, nearly beyond the point where vegetation can subsist, and surrounded by volcanoes and sulphur-pits, continually emitting volumes of smoke. The wretched inhabitants of these deserts have no food but potatoes: and if these fail, as they did last year, they go to the mountains to eat the stem of a little tree called *achupalla* (*pourretia pitcarnia*); but the bears of the Andes, as they too feed on it, often dispute it with them. On the north of the volcano of Pasto, I discovered in the little Indian village of Voisaco, 1900 yards above the level of the sea, a red porphyry, with base of argil, enclosing vitreous feldspar, and hornblende, that has all the properties of the serpentine of the *Fichtelgebirge*. This porphyry has very distinctly marked poles, but no attractive power. Near the town of Ibarra, we nearly escaped being drowned by a very sudden swell of the water, accompanied with shocks of an earthquake.

We reached Quito on the 6th of January 1802. It is a handsome city; but the sky is commonly clouded and gloomy. The neighbouring mountains exhibit little verdure, and the cold is very considerable. The great earthquake on the 4th of February 1797; which changed the face of the whole province, and in one instant destroyed thirty-five or forty thousand persons, has so altered the temperature of the air, that the thermometer is now commonly 41° to 54°, and seldom rises to 68° or 70°, whereas Bouguer observed it constantly at 66° or 68°. Since this catastrophe, earthquakes are continually recurring; and such shocks! it is probable, that all the higher ground is one vast volcano. What are called the mountains of Cotopoxi and Pichincha, are but little summits, the craters of which, form different conduits terminating in the same cavity. The earthquake of 1797, afforded a melancholy proof of this; for the ground then opened every where, and vomited forth sulphur, water, &c. Notwithstanding the dangers and horrors that surround them, the people of Quito are gay, lively, and sociable; and in no place did I ever see a more decided and general taste for pleasure, luxury, and amusement. Thus man accustoms himself to sleep tranquilly on the brink of a precipice.

I was twice at the mouth of the crater of Pichincha, the mountain that overlooks the city of Quito. I know of no one but Condamine, that ever reached it before; and he was without instruments, and could not stay above a quarter of an hour, on account of the extreme cold. I was more successful. From the edge of the crater rise three peaks, which are free from snow, as it is continually melted by the ascending vapour. At the summit of one of these I found a rock, that projected over the precipice, and hence I made my observations. This rock was about twelve feet long, by six broad, and strongly agitated by the frequent shocks, of which we counted eighteen in less than half an hour. We lay on our bellies, the better to examine the bottom of the crater. The mouth of the volcano forms a circular hole, near a league in circumference, the perpendicular edges of which are covered with snow on the top. The inside is of a deep black; but the abyss is so vast, that the summits of several mountains may be distinguished in it. Their tops seemed to be six hundred yards below us, judge then where their bases must be. I have no doubt that the bottom of the crater is on a level with the city of Quito. Condamine found it

extinct, and even covered with snow; but we had to report the unpleasant news, that it was burning. On my second visit, being better furnished with instruments, I found the diameter of the crater to be 1600 yards, whereas that of Vesuvius is but 670. The height of the mountain is 5280 yards.

When we visited the volcano of Antisana, the weather was so favourable, that we reached the height of 5915 yards. In this lofty region, the barometer sunk to 14 inches 7 lines, [15.6 Eng.] and the tenuity of the air occasioned the blood to issue from our lips, gums, and even eyes: we felt extremely feeble, and one of our company fainted away. The air brought from the loftiest point we visited, gave on being analysed 0.218 of oxigen gas, and 0.008 of carbonic acid.

We visited Cotopoxi, but could not reach the mouth of the crater. The assertion, that this mountain was diminished in height by the earthquake of 1797, is a mistake.

In June we proceeded to measure Chimboraco and Tunguragua, and take a plan of all the country affected by the grand catastrophe of 1797. We approached within about 500 yards of the summit of Chimboraco, our ascent being facilitated by a line of volcanic rocks uncovered with snow. The height we reached was 6465 yards; and we were prevented from ascending farther by a chasm too deep to cross. We felt the same inconveniences as on Antisana; and were unwell for two or three days after. The air at this height contained 0.20 of oxygen. The trigonometrical measurement I took of the mountain at two different times, and I can place some confidence in my operations, gave me for its height 6970 yards, a hundred more than Condamine assigns it. The whole of this huge mass, as of all the high mountains of the Andes, is not granite, but porphyry, from the foot to the summit, and there the porphyry is 4050 yards thick.

Chimboraco is probably a volcanic mountain, for the track by which we ascended, consists of a burnt and scorified rock mixed with pumice-stone, resembling all the streams of lava in this country, and ran higher up the mountain than we could climb. The summit therefore is in all likelihood the crater of an extinct volcano.

The mountain of Tunguragua has diminished in height since the earthquake of 1797. Bouguer assigns it 5589 yards, I found it but

5399, so that it must have lost 190 yards; and indeed the people in the vicinity say, that they have seen its summit crumble away before their eyes.

During our stay at Riobancha, we accidentally made a very curious discovery. The state of the province of Quito, previous to its conquest by the Inca Tupaynpangi, in 1470, is wholly unknown: but the king of the Indians, Leandro Zapla, who resides at Lican, and has a mind extraordinarily cultivated for an Indian, possesses manuscripts composed by one of his ancestors, in the sixteenth century, which contains the history of that period. They are written in the Paraguay tongue, which was formerly general in Quito, but is now lost, having been supplanted by the Inca. Fortunately another of Zapla's ancestors amused himself by translating these memoirs into Spanish. We have obtained from them valuable information, particularly in the memorable period of the eruption of Nevado del Atlas, which must have been the highest mountain in the world, loftier than Chimboraco, and called by the Indians *Capa-urca*, or chief of mountains.

[*Bouguer. Estalla. Humboldt.*]

SECTION III.

Volcanic Phænomena in the West Indies.

ALTHOUGH active volcanoes are by no means common in the islands distinguished by the name of the West Indies, there are few of them that do not betray some traces either of a volcanic origin or of volcanic effects. The Caribees are particularly characterised by such features, and especially Martinique, Guadaloupe, and St. Lucia. The mountain-soil of the first of these consists, to a very considerable extent, of pumice, either in lumps or powder, occasionally intermixed with a ferruginous sand, which is not unfrequently a volcanic production.

On the island of St. Lucie, or St. Lucia, are some high and craggy mountains, which bear evident marks of volcanoes; in one deep valley there are several ponds, the water of which boils up in a very powerful manner, and the streams that issue from it retain their heat at the distance of three miles from their source.

The mountains of Guadaloupe are, according to De Borda, not less lofty than those of Martinique, and the Souffriere or Sulphur

Mountain, ejected both smoke and flames during the time of his visit to the island. This very singular mountain is the highest of the whole; its summit is perfectly bare, nothing growing upon it but ferns, mosses, and a few other cryptogamic plants: but it affords a fine view of the neighbouring islands of Dominica, Marie-galante, Martinico, Montserrat, Nevis, and various others. Upon the highest part is a rugged platform, covered with burnt stones of all sizes; and from several clefts and chinks issue smoke. On the east side are two mouths, which open into a pit of sulphur, one of which is an oval hole of about an hundred feet in its greatest diameter, out of which also frequently arise thick clouds of black smoke, accompanied with sparks of fire. The negroes who sell brimstone fetch it from this mountain. About two hundred paces below the lowest of these mouths are three pools of very hot water, four or five paces from each other: the water of the largest is very dark coloured, and smells like that of a smith's forge; the second is whitish, and has the taste of alum; the third is blue, and has a vitriolic taste. Here are also several springs, which, uniting their streams, form various torrents. The middle and bottom of this burning mountain are extremely different from the top of it, being covered with tall trees and herbage, watered by a number of rivulets, and cultivated with the utmost care and industry.

Almost every island in the western Archipelago, particularly those which have the highest land, has, in like manner, its *Sulphur-hill*, or *Souffrière*, as it is denominated by the French. In some of these the volcano has become extinct, and is no longer to be traced; but in others, as Guadaloupe, St. Lucia, and St. Vincent, there are decided and well-characterised craters, which are occasionally active, and throw out ashes, scoriæ, and lava with the flame.

The most singular of these Souffrières occurs in the island of Montserrat, and is thus ably described by Dr. Nugent. " The island of Montserrat, so called by the Spaniards from a fancied resemblance to the celebrated mountain of Catalonia, is every where extremely rugged and mountainous, and the only roads, except in one direction, are narrow bridle-paths winding through the recesses of the mountains; there is hardly a possibility of using wheeled carriages, and the produce of the estates is brought to the place of shipment on the backs of mules. Accompanied by a friend, I accordingly set out on horseback from the town of Plymouth, which

is situated at the foot of the mountains on the sea shore. We proceeded by a circuitous and steep route about six miles, gradually ascending the mountain, which consisted entirely of an uniform porphyritic rock, broken every where into fragments and large blocks, and which in many places was so denuded of soil as to render it a matter of astonishment how vegetation, and particularly that of the cane, should thrive so well. The far greater part of the whole island is made up of this porphyry, which by some systematics would be considered as referable to the newest floëtz trap formation, and by others would be regarded only as a variety of lava. It is a compact and highly-indurated argillaceous rock of a grey colour, replete with large and perfect crystals of white felspar and black hornblende. Rocks of this description generally pass in the West Indies by the vague denomination of fire-stone, from the useful property they possess of resisting the operation of intense heat. A considerable quantity of this stone is accordingly exported from Montserrat to the other islands which do not contain it, being essential in forming the masonry around the copper boilers in sugar-works. We continued our ride a considerable distance beyond the estate called Galloway's (where we procured a guide) till we came to the side of a very deep ravine which extends in a winding direction the whole way from one of the higher mountains to the sea. A rugged horse-path was traced along the brink of the ravine, which we followed amidst the most beautiful and romantic scenery. At the head of this ravine is a small amphitheatre formed by lofty surrounding mountains, and here is situated what is termed "The Sulphur." Though the scene was extremely grand and well worthy of observation, yet I confess I could not help feeling a good deal disappointed, as there was nothing like a crater to be seen, or any thing else that could lead me to suppose the place had any connexion with a volcano. On the north, east, and west sides were lofty mountains wooded to the tops, composed apparently of the same kind of porphyry we had noticed all along the way. On the south, the same kind of rock of no great height, quite bare of vegetation, and in a very peculiar state of decomposition. And on the south-eastern side, our path and the outlet into the ravine. The whole area thus included, might be three or four hundred yards in length, and half that distance in breadth. The surface of the ground, not occupied by the ravine, was broken and strewed with fragments and

and masses of the porphyritic rock, for the most part so exceedingly decomposed as to be friable and to crumble on the smallest pressure. For some time I thought that this substance, which is perfectly white, and in some instances exhibits an arrangement like crystals, was a peculiar mineral; but afterwards became convinced, that it was merely the porphyritic rock singularly altered, not by the action of the air or weather, but, as I conjecture, by a strong sulphureous or sulphuric acid vapour which is generated here, and which is probably driven more against one side by the eddy wind up the ravine, the breeze from any other quarter being shut out by the surrounding hills*.

Amidst the loose stones and fragments of decomposed rock are many fissures and crevices, whence very strong sulphureous exhalations arise, and which are diffused to a considerable distance; these exhalations are so powerful as to impede respiration, and near any of the fissures are quite intolerable and suffocating. The buttons of my coat, and some silver and keys in my pockets, were instantaneously discoloured. An intense degree of heat is at the same time evolved, which, added to the apprehension of the ground crumbling and giving way, renders it difficult and painful to walk near any of these fissures. The water of a rivulet which flows down the sides of the mountain and passes over this place, is made to boil with violence, and becomes loaded with sulphureous impregnations. Other

* This peculiar decomposition of the surrounding rock has been frequently observed in similar situations, and under analogous circumstances, and has I find been accounted for by other persons in the same way: thus Dolomieu says, "La couleur blanche des pierres de l'interieur de tous les craters inflammés est due à une veritable alteration de la lave produite par les vapeurs acido-sulfureuses qui les penetrent, et qui se combinent avec l'argile qui leur sert de base, y formant l'alun que l'on retire des matières volcaniques." *Voy. aux Isles de Lipari*, p. 18.

And he afterwards adds, "Cette alteration des laves par les vapeurs acido-sulfureuses, est une espèce d'analyse que la nature fait elle même des matières volcaniques. Il y a des laves sur lesquelles les vapeurs n'ont pas encore eu assez de tems d'agir pour les dénaturer entièrement, et alors on les voit dans différens etats de decomposition que l'on reconnoit par le couleur."

Alum is doubtless formed at this place, as well as elsewhere, under similar circumstances: the potash necessary for the composition of this salt, being, as well as the argil, derived from the surrounding rock.

branches of the same rivulet which do not pass immediately near these fissures, remain cool and limpid; and thus you may with one hand touch one rill that is at the boiling point, and with the other hand touch another rill which is of the usual temperature of water in that climate. The exhalations of sulphur do not at all times proceed from the same fissures, but new ones appear to be daily formed, others becoming, as it were, extinct. On the margins of these fissures, and indeed almost over the whole place, are to be seen most beautiful crystallizations of sulphur, in many spots quite as fine and perfect as those from Vesuvius, or indeed as any other specimens I have ever met with. The whole mass of decomposed rock in the vicinity is, in like manner, quite penetrated by sulphur. The specimens which I collected of the crystallized sulphur, as well as of the decomposed and undecomposed porphyry, were left inadvertently on board the packet at Falmouth, which prevents my having the pleasure of exhibiting them to the Society. I did not perceive at this place any trace of pyrites, or any other metallic substance, except indeed two or three small fragments of clay ironstone at a little distance, but did not discover even this substance any where *in situ*. It is very probable that the bed of the glen or ravine might throw some light on the internal structure of the place; but it was too deep, and its banks infinitely too precipitous, for me to venture down to it. I understood that there was a similar exhalation and deposition of sulphur on the side of a mountain not more than a mile distant in a straight line; and a subterranean communication is supposed to exist between the two places.

[*De Borda, Journal des Mines, Geological Transact.* Vol. I.]

CHAP. XVI.

ISLANDS SUDDENLY THROWN UP FROM THE SEA.

BESIDES the convulsions of nature displayed in volcanoes, other operations are carried on below the fathomless depths of the sea, the nature of which can only be conjectured of by the effects pro-

duced; nor is it more astonishing that inflammable substances should be found beneath the bottom of the sea, than at similar depths on land, and that there the impetuous force of fire should cause the imprisoned air and elastic gasses to expand, and by its mighty force drive the earth at the bottom of the sea above its surface. These marine volcanoes are perhaps more frequent, though they do not so often come within the reach of human observation, as those on land; since stupendous must be the operations carried on which never throw up matter to such an extent as man's ingenuity enables him to reach by fathoming.

Many instances have occurred, both in ancient and modern times, of islands being formed in the midst of the sea, and their appearance has always been preceded by violent agitations of the surrounding waters, accompanied with dreadful noises, and in some instances, with fiery eruptions from the new-formed isles, which are composed of various substances, but frequently intermixed with a considerable quantity of volcanic lava. Such islands remain for ages barren, but in a long course of time become abundantly fruitful. It is obvious to enquire, whether springs are found on such new-created spots, when the convulsions which gave them birth have subsided; but on that point it is probable that no certain information has been obtained, as it does not appear that any naturalist has visited them for the purpose of recording their properties.

Among the writers of antiquity who have transmitted accounts of islands which have thus started up to the astonished spectator, Seneca asserts, that, in his time, the island of Therasea, in the Egean sea, was seen to rise in this manner, by some mariners who were sailing near the point of its ascent*. Pliny gives a yet more wonderful account; for he says, that in the Mediterranean thirteen islands appeared at once emerging from the sea, the cause of which he ascribes rather to the retiring of the waters, than to any subterraneous energy; but he speaks of the island Hiera, near to that of Theresea, as formed by subterraneous explosions, and enumerates several others as derived from a similar origin, in one of which, he says, that fishes were found in great abundance, and that whoever ate of them died soon afterwards.

It is, however, to the Archipelago, and the Azores, that we

* Theresiam nostræ ætatis insulam spectantibus nostris in Ægeo mari enatum. Quæst. Nat. lib. vi. cap. xxi.

must look for the grandest and most surprising instances of this phenomenon. Let us take an example or two from each of these groupes of islands.

The island of Acroteri, of no mean fame in ancient history, appears to have its surface composed of pumice-stone, encrusted with a surface of fertile earth, and the ancients represent it as rising, in a violent earthquake, out of the sea. Four neighbouring islands have had a similar origin, and yet the sea is here of such a depth as to be unfathomable by any sounding-line. These arose at different times; the first long before the commencement of the christian æra, the second in the first century, the third in the eighth, and the fourth in 1573.

The following history, appertaining to the same cluster, is of still later date; and its peculiarities entitle it to a more minute detail:—

On May 22, 1807, a severe earthquake was felt at Great Cammeni; and on the ensuing morning a party of seamen discovering not far off what they believed to be a wreck, rapidly rowed towards it; but finding rocks and earth instead of the remains of a ship, hasted back, and spread the news of what they had seen in Santorini. How great soever the apprehensions of the inhabitants were at the first sight, their surprise soon abated, and in a few days, seeing no appearance of fire or smoke, some of them ventured to land on the new island. Their curiosity led them from rock to rock, where they found a kind of white stone that cut like bread, which it nearly resembled in its form, colour, and consistence. They also found many oysters sticking to the rocks; but while they were employed in gathering them, the island moved and shook under their feet, upon which they ran with precipitation to their boats. With these motions and tremblings the island increased, not only in height, but in length and breadth; yet sometimes while it was raised and extended on one side, it sunk aud diminished on the other. Our author observed a rock to rise out of the sea, forty or fifty paces from the island, which having continued four days, sunk, and appeared no more; but several others appeared and disappeared alternately, till at last they remained fixed and unmoved. In the mean time the colour of the surrounding sea was changed: at first it was of a light green, then reddish, and afterwards of a pale yellow, accompanied with a noisome stench, which spread itself over part of Santorini.

On the 16th of July the smoke first appeared, not indeed from

having never been so frequent or so dreadful as on that and the following day. The bursts of this subterranean thunder, like a general discharge of the artillery of an army, were repeated ten or twelve times within twenty-four hours, and immediately after each clap the large furnace threw up huge red-hot stones, which fell into the sea at a great distance. These claps were always followed by a thick smoke, which spread clouds of ashes over the sea and the neighbouring islands.

On the 18th of September, an earthquake was felt at Santorini, but did no great damage, though it considerably enlarged the burning island, and in several new places gave vent to the fire and smoke. The claps were also more terrible than ever, and in the midst of a thick smoke that appeared like a mountain, were seen and heard large pieces of rock, thrown up with as much noise and force as balls from the mouth of a cannon, which afterward fell upon the island, or into the sea. One of the small neighbouring islands was several times covered with these fiery stones, which being thinly crusted over with sulphur, gave a bright light, and continued burning till that was consumed.

On the 21st, after a dreadful clap of subterraneous thunder, very great lightnings ensued, and at the same instant the new island was so violently shaken, that part of the great furnace came tumbling down, and huge burning rocks were thrown to the distance of two miles and upward. This seemed to be the last effort of the volcano, and to have exhausted the combustible matter, as all was quiet for several days after. But on the 25th the fire broke out again with still greater fury, and among the claps one was so terrible, that the churches of Santorini were soon filled with crowds of people, expecting every moment would be their last; and the castle and town of Scaro suffered such a shock, that the doors and windows of the houses flew open. The volcano continued to rage during the remaining part of the year; and in the month of January 1708, the large furnace, without one day's intermission, threw out stones and flames, at least once or twice, but generally five or six times a day.

On the 10th of February, in the morning, a pretty strong earthquake was felt at Santorini, which the inhabitants considered as a prelude to greater commotions in the burning island; nor were they deceived; for soon after the fire and smoke issued in prodigious

quantities, the claps like thunder were redoubled, and nothing appeared but objects of horror and confusion; rocks of an amazing size were raised up to a great height above the water, and the sea raged and boiled to such a degree that it occasioned great consternation. The subterraneous bellowings were heard without intermission, and sometimes in less than a quarter of an hour there were six or seven eruptions from the large furnace. The noise of the repeated claps, the quantity of huge stones that flew about on every side, the houses tottering to their very foundations, and the fire, which now appeared in open day, surpassed all that had hitherto happened, and formed a scene astonishing beyond description.

The 15th of April was rendered remarkable by the number and violence of the bellowings and eruptions, by one of which near a hundred large stones were thrown up all together into the air, and fell again into the sea at about two miles distance. From this time to the 23d of May, which might be called the anniversary of the birth of the new island, things continued much in the same state; but afterward the fire and smoke by degrees subsided, and the subterraneous thunders became less terrible.

On the 15th of July 1709, the Bishop of Santorini, accompanied by several friars, hired a boat to take a near view of the island. They made directly toward it on that side where the sea did not bubble, but where it smoked very much. Being got into this vapour, they felt a close suffocating heat, and found the water very hot; upon which they directed their course toward a part of the island at the farthest distance from the large furnace. The fires, which still continued to burn, and the boiling of the sea, obliged them to take a great compass, and yet they felt the air about them very hot and sultry. Having encompassed the island, and surveyed it carefully from an adjacent one, they judged it to be two hundred feet above the sea, about a mile broad, and five miles in circumference; but not being thoroughly satisfied, they resolved to attempt to land, and accordingly rowed toward that part of the island where they perceived neither fire nor smoke; but when they had got within a hundred yards of it, the great furnace discharged itself with its usual fury, and the wind blew upon them a thick smoke and a shower of ashes, which obliged them to quit their design. Having retired a little, they let down a plummet, with a line ninety-five fathoms long, but it was too short to reach the bottom. On their

return to Santorini, they observed that the heat of the water had melted most of the pitch from their boat, which was therefore grown very leaky.

From this time until the 15th of August, the fire, smoke, and noise continued, though moderately; and for several years after, it appears that the island still increased, but that the fire and subterraneous noises were much abated; and as the travellers who have since visited the Levant give no account of its burning, it has doubtless long since ceased.

We have stated that similar eruptions of islands have occurred in the group of the Azores. Thus, in December 1720, a violent earthquake was felt on the island of Tercera. In the night and the next morning the top of a new island appeared, which ejected a huge column of smoke. The pilot of a ship, who attempted to approach it, sounded on one side of the new-formed island, with a line of sixty fathoms, but could find no bottom. On the opposite side, the sea was deeply tinged with various colours, white, blue, and green, and was very shallow. This island was larger on its first appearance than at some distance of time afterwards: it at length sunk below the level of the sea, and now is no more to be found.

"Yet what can be more surprising," observes the writer of the preceding account, "than to see fire not only break out of the bowels of the earth, but also to make itself a passage through the waters of the sea! What can be more extraordinary or foreign to our common notions of things, than to see the bottom of the sea rise up into a mountain above the water, and become so firm an island as to be able to resist the violence of the greatest storms! I know that subterraneous fires, when pent in a narrow passage, are able to raise up a mass of earth as large as an island; but that this should be done in so regular and exact a manner that the water of the sea should not be able to penetrate and extinguish those fires; and, after having been extinguished, that the mass of earth should not fall down, or sink again with its own weight, but still remain in a manner suspended over the great arch below! This is what to me seems more surprising than any thing that has been related of Mount Etna, Vesuvius, or any other volcano."

The following is a more detailed description of a similar phenomenon occurring in the same quarter, though of much later date. We copy it from Capt. Tillard's narrative, communicated to the Royal Society.

APPROACHING, says he, the island of St. Michael's, on Sunday, June 12, 1811, in his Majesty's sloop Sabrina under my command, we occasionally observed, rising in the horizon, two or three columns of smoke, such as would have been occasioned by an action between two ships, to which cause we universally attributed its origin. This opinion was, however, in a very short time changed, from the smoke increasing and ascending in much larger bodies than could possibly have been produced by such an event; and having heard an account, prior to our sailing from Lisbon, that in the preceding January or February a volcano had burst out within the sea near St. Michael's, we immediately concluded that the smoke we saw proceeded from that cause, and on our anchoring next morning in the road of Ponta del Gada, we found this conjecture correct as to the cause, but not to the time; the eruption of January having totally subsided, and the present one having only burst forth two days prior to our approach, and about three miles distant from the one before alluded to.

Desirous of examining as minutely as possibly a contention so extraordinary between two such powerful elements, I set off from the city of Ponta del Gada on the morning of the 14th, in company with Mr. Read, the Consul General of the Azores, and two other gentlemen. After riding about twenty miles across the NW. end of the island of St. Michael's, we came to the edge of a cliff from whence the volcano burst suddenly upon our view in the most terrific and awful grandeur. It was only a short mile from the base of the cliff, which was nearly perpendicular, and formed the margin of the sea; this cliff being as nearly as I could judge from three to four hundred feet high. To give you an adequate idea of the scene by description is far beyond my powers; but for your satisfaction I shall attempt it.

Imagine an immense body of smoke rising from the sea, the surface of which was marked by the silvery ripling of the waves, occasioned by the light and steady breezes incidental to those climates in summer. In a quiescent state, it had the appearance of a circular cloud revolving on the water like an horizontal wheel, in various and irregular involutions, expanding itself gradually on the lee side, when suddenly a column of the blackest cinders, ashes, and stones would shoot up in form of a spire at an angle of from ten to twenty degrees from a perpendicular line, the angle of inclination being universally to windward: this was rapidly succeeded by a second, third, and

fourth, each acquiring greater velocity, and overtopping the other till they had attained an altitude as much above the level of our eye, as the sea was below it.

As the impetus with which the columns were severally propelled, diminished, and their ascending motion had nearly ceased, they broke into various branches resembling a groupe of pines, these again forming themselves into festoons of white feathery smoke in the most fanciful manner imaginable, intermixed with the finest particles of falling ashes, which at one time assumed the appearance of innumerable plumes of black and white ostrich feathers surmounting each other; at another, thatof the light wavy branches of a weeping willow.

During these bursts, the most vivid flashes of lightning continually issued from the densest part of the volcano; and the cloud of smoke now ascending to an altitude much above the highest point to which the ashes were projected, rolled off in large masses of fleecy clouds, gradually expanding themselves before the wind in a direction nearly horizontal, and drawing-up to them a quantity of water-spouts, which formed a most beautiful and striking addition to the general appearance of the scene.

That part of the sea where the volcano was situated, was upwards of thirty fathoms deep, and at the time of our viewing it the volcano was only four days old. Soon after our arrival on the cliff, a peasant observed he could discern a peak above the water: we looked, but could not see it; however, in less than half an hour it was plainly visible, and before we quitted the place, which was about three hours from the time of our arrival, a complete crater was formed above the water, not less than twenty feet high on the side where the greatest quantity of ashes fell; the diameter of the crater being apparently about four or five hundred feet.

The great eruptions were generally attended with a noise like the continued firing of cannon and musquetry intermixed, as also with slight shocks of earthquakes, several of which having been felt by my companions, but none by myself, I had become half sceptical, and thought their opinion rose merely from the force of imagination; but while we were sitting within five or six yards of the edge of the cliff, partaking of a slight repast which had been brought with us, and were all busily engaged, one of the most magnificent bursts took place which we had yet witnessed, accompanied

by a very severe shock of an earthquake. The instantaneous and involuntary movement of each was to spring upon his feet, and I said, "This admits of no doubt." The words had scarce passed my lips, before we observed a large portion of the face of the cliff, about fifty yards on our left, falling, which it did with a violent crash. So soon as our first consternation had a little subsided, we removed about ten or a dozen yards further from the edge of the cliff, and finished our dinner.

On the succeeding day, June 15th, having the consul and some other friends on board, I weighed, and proceeded with the ship towards the volcano, with the intention of witnessing a night view; but in this expectation we were greatly disappointed, from the wind freshening and the weather becoming thick and hazy, and also from the volcano itself being clearly more quiescent than it was the preceding day. It seldom emitted any lightning, but occasionally as much flame as may be seen to issue from the top of a glass-house or foundery chimney.

On passing directly under the great cloud of smoke, about three or four miles distant from the volcano, the decks of the ship were covered with fine black ashes, which fell intermixt with small rain. We returned the next morning, and late on the evening of the same day I took my leave of St. Michael's to complete my cruize.

On opening the volcano clear of the NW part of the island, after dark on the 16th, we witnessed one or two eruptions that, had the ship been near enough, would have been awfully grand. It appeared one continued blaze of lightning; but the distance which it was at from the ship, upwards of twenty miles, prevented our seeing it with effect.

Returning again towards St. Michael's on the 4th of July, I was obliged, by the state of the wind, to pass with the ship very close to the island, which was now completely formed by the volcano, being nearly the height of Matlock High Tor, about eighty yards above the sea. At this time it was perfectly tranquil; which circumstance determined me to land, and explore it more narrowly.

I left the ship in one of the boats, accompanied by some of the officers. As we approached, we perceived that was still smoking in many parts, and upon our reaching the island found the surf on the beach very high. Rowing round to the lee side, with some little

difficulty, by the aid of an oar, as a pole, I jumped on shore, and was followed by the other officers. We found a narrow beach of black ashes, from which the side of the island rose in general too steep to admit of our ascending; and where we could have clambered up the mass of matter was much too hot to allow our proceeding more than a few yards in the ascent.

The declivity below the surface of the sea was equally steep, having seven fathoms water scarce the boat's length from the shore, and at the distance of twenty or thirty yards we sounded twenty-five fathoms.

From walking round it in about twelve minutes, I should judge that it was something less than a mile in circumference; but the most extraordinary part was the crater, the mouth of which, on the side facing St. Michael's, was nearly level with the sea. It was filled with water, at that time boiling, and was emptying itself into the sea by a small stream about six yards over, and by which I should suppose it was continually filled again at high water. This stream, close to the edge of the sea, was so hot, as only to admit the finger to be dipped suddenly in, and taken out again immediately.

It appeared evident, by the formation of this part of the island, that the sea had, during the eruptions, broke into the crater in two places, as the east side of the small stream was bounded by a precipice, a cliff between twenty and thirty feet high forming a peninsula of about the same dimensions in width, and from fifty to sixty feet long, connected with the other part of the island by a narrow ridge of cinders and lava, as an isthmus of from forty to fifty feet in length, from which the crater rose in the form of an amphitheatre.

This cliff, at two or three miles distance from the island, had the appearance of a work of art resembling a small fort or block-house. The top of this we were determined, if possible, to attain; but the difficulty we had to encounter in doing so was considerable; the only way to attempt it was up the side of the isthmus, which was so steep that the only mode by which we could effect it, was by fixing the end of an oar at the base, with the assistance of which we forced ourselves up in nearly a backward direction.

Having reached the summit of the isthmus, we found another difficulty, for it was impossible to walk upon it, as the descent on

the other side was immediate, and as steep as the one we had ascended; but by throwing our legs across it, as would be done on the ridge of a house, and moving ourselves forward by our hands, we at length reached that part of it where it gradually widened itself and formed the summit of the cliff, which we found to have a perfectly flat surface, of the dimensions before stated.

Judging this to be the most conspicuous situation, we here planted the Union, and left a bottle sealed up containing a small account of the origin of the island, and of our having landed upon it, and naming it Sabrina Island.

Within the crater I found the complete skeleton of a guard fish, the bones of which being perfectly burnt, fell to pieces upon attempting to take them up; and by the account of the inhabitants on the coast of St. Michael's, great numbers of fish had been destroyed during the early part of the eruption, as large quantities, probably suffocated or poisoned, were occasionally found drifted into the small inlets or bays.

The island, like other volcanic productions, is composed principally of porous substances, and generally burnt to complete cinders, with occasional masses of a stone, which I should suppose to be a mixture of iron and lime-stone.

[*Lowenorn. Payne's Geog. Extr. Phil. Trans.* 1728. 1812.]

CHAP. XVII.

MINERALOGICAL REMARKS ON THE NATURE OF VOLCANIC MATERIALS.

THIS is a subject which still requires the attention of oryctologists. We are scarcely acquainted, says Dr. Thomson in his History of the Royal Society, with the nature of the rocks of which Etna or Vesuvius is composed: indeed, the task is extremely difficult; for these mountains are so surrounded with lava on all sides, that the rock itself, of which the mountain consisted before the volcano commenced, may perhaps be entirely concealed from view. The prodigious extent of

Etna, about a hundred miles in circumference, and the vast number of volcanic hills attached to its sides, at least forty-four in number, render the geognostic examination of the rocks, of which it was originally composed, almost impossible. Sir William Hamilton and several other writers on volcanoes suppose, that, previous to the commencement of the volcano, no mountain whatever existed; and that the whole mountain has been formed by successive eruptions from the crater. But this opinion is both improbable in itself, and destitute of evidence. Werner conceives, that volcanic hills are always composed of green stone, basalt, and the other rocks which constitute the independent coal formation, and the floetz-trap. But the observations of Humboldt, on the volcanoes of America, will not admit of such conclusions; unless, indeed, we conceive granite and porphyry to belong to these formations; a supposition not very improbable, if we attend to the late observations of Von Buch and Professor Jameson; the former of whom in Norway, and the latter in Scotland, have found granite among secondary rocks.

Geologists are still deplorably ignorant of every thing relating to volcanic rocks. As a proof of this, it may be stated with truth, that the best treatise on volcanoes, which has hitherto appeared, was written by Bergmann, and published before the year 1780. Even lava itself, or the melted matter which issues from volcanoes, has been frequently confounded with basalt and green-stone. At one time it was the fashion to consider all hills composed of these two last rocks; and, in short, all floetz-trap hills as extinct volcanoes. Thus, Fojas de St. Fond, in his travels through Scotland, finds every where abundance of extinct volcanoes; and Mr. Raspe inserted a paper in the Philosophical Transactions, describing similar hills in Hessia, under the same appellation *. In like manner, the hills of Auvergne, in France, have been considered as extinct volcanoes by the French mineralogists; even D'Aubaisson, who was educated in an opposite school, has come to the same conclusion. Notwithstanding this, there can be little doubt that these hills stand in the same predicament with the floetz-trap hills of Scotland and Germany. These opinions, respecting the volcanic nature of basalt and green-stone, are now pretty generally laid aside. The followers of

* Phil. Trans. 1771. vol. lxi. p. 580.

Dr. Hutton, indeed, contend that they have been melted by heat, but do not suppose that they have ever belonged to a volcanic mountain.

Considerable doubts are entertained by some, whether pumice be a volcanic substance or not; and these doubts are founded on the supposition that pumice, though often observed in the neighbourhood of volcanoes, has never been seen mixed with lava, or actually flowing from a volcano. If the evidence of Tournefort be considered as sufficient, there can be no doubt that pumice is occasionally thrown out of volcanoes; for he describes various examples of it in his Voyage to the Levant. Pumice has been repeatedly observed floating on the surface of the sea, in immense quantity. To give one example, Mr. Dove, the captain of an Indiaman, observed it floating in the Atlantic Ocean, in immense abundance, over a tract of not less than 317 miles in length. The pumice was first observed in south latitude 35° 36′, west longitude 4° 9′, and the shoals of it continued for several days *. Now it is impossible to account for such appearances on any other supposition than that the pumice has been thrown from the bottom of the sea by some volcanic force; and, if that be admitted, it will follow that pumice, at least some times, though perhaps not always, is volcanic.

The following observations of Spalanzani upon an accurate investigation of the Solfatara †, near Naples, are peculiarly entitled to the attention of the mineralogist.

* Phil. Trans. 1728. vol. xxxv. p. 444.

† The lofty side of Solfatara, near Naples, seems to exhibit, in a minuter degree, whatever is seen of this horrible kind on the great theatre of nature. This plain, which is about twelve hundred feet long, and a thousand broad, is embosomed in mountains, and has in the middle of it a lake of noisome blackish water, covered with a bitumen that floats upon its surface. In every part of this plain, caverns appear smoking with sulphur, and often emitting flames. The earth, wherever we walk over it, trembles beneath the feet. Noises of flames, and the hissing of waters, are heard at the bottom. The water sometimes spouts up eight or ten feet high. The most noisome fumes, fœtid water, and sulphureous vapours, offend the smell. A stone thrown into any of the caverns, is ejected again with considerable violence. These appearances generally prevail when the sea is any ways disturbed; and the whole seems to exhibit marks of an earthquake in miniature.

The beautiful city of Naples is entirely founded on volcanic substances. Among these the tufa predominates, which has also contributed not a little to the materials of many buildings. To the north and west it is accumulated in large heaps, and forms spacious hills. A philosophical stranger, on his arrival in this country, when he views these immense masses of a substance which must excite in his mind the idea of fire, cannot but feel astonishment, and enquire with a kind of serious thoughtfulness, what has been their origin. It is known that on this subject naturalists are divided. Some conjecture that the volcanic tufa was generated within the sea when it bathed the foot of the burning mountains; others suppose that the cinders ejected by the fire, have, in a long course of years, been hardened into this species of stone by the filtration of rain water; lastly, others incline to think that the tufa derives its origin from the slimy and fluid substances thrown out by the volcanoes in some of their eruptions.

The diversity of volcanic tufas has, perhaps, been the cause of these different opinions, each of which may possibly be true with respect to different kinds of tufa. Those, however, which are found in the vicinity of Naples are probably the produce of thick eruptions, as we may conclude from the curious discovery of Sir William Hamilton, who, in digging up, in the tufa which had covered Herculaneum, the head of an antique statue, observed that the perfect impression of the head was visible in the tufa, which cannot be supposed to have happened but by its having enveloped the statue in a liquid or moist state.

To the observation of Sir William let me be permitted to add one of my own, which I made in the grotto of Posilipo. It is well known that this grotto has been excavated within the tufa, and serves as a public road from Naples to Pozzuolo. This tufa, which is of a clear grey, has for its base an earth in part argillaceous, of a slight hardness, which contains vitreous flakes, pieces of feltspars and fragments of yellowish pumice-stone, which by the changes it has undergone has become extremely friable, and almost reducible to powder. This tufa has been in some measure analysed by the excavation made in by art, which furnishes a proof of the nature of its origin. For if any person, in the summer time, enters the grotto about the rising of the sun, since at other times of the day there is

not sufficient light; the solar rays, shining on the entrance which looks towards Naples, will sufficiently illuminate the roof and sides to shew layers or flakes, similar to those which may be observed on the steep sides of mountains, or in perpendicular sections of the earth, in low places, where sediments of various kinds of slime have been formed by the inundations of rivers. It seems, however, impossible to doubt, that this accumulation of tufa, through the midst of which the Romans opened that long and spacious grotto, has been produced by the thick eruptions which have frequently issued from volcanoes, and which, heaping up one upon another, have hardened in time into this tufaceous stone; since both Vesuvius and Etna furnish sufficient examples of such eruptions. And as in many other tufas in the vicinity I have observed a similar constructure, I cannot suppose their origin to have been different.

Coming out of this subterraneous passage, and proceeding towards Solfatara, I observed, on the right-hand side of the road, a ridge of lava, nearly parallel with it, which had every appearance of having been thrown out of the volcano when burning, both because it was extremely near to it, and had its highest part in that direction. Its thickness exceeded five-and-thirty feet, and it was situated between two layers of tufa, one above and the other below. It formed a high rock, perpendicular to one side of the road. A number of labourers were continually employed in separating pieces of this lava, with pickaxes, or other instruments proper for such work. It is compact, heavy, somewhat vitreous, gives sparks with steel, and appeared to me to have for its base the petrosilex. Incorporated with it are found shoerls and feltspars. The former are shining, of a dark violet-colour, in shape rectangular needles, vitreous, in length from the sixth of a line to two lines: it besides contains a considerable quantity of others which have no regular form. But the feltspars are more conspicuous than the shoerls; both from their larger size and greater number. They are, in general, of a flat rhomboidal form, and consist of an aggregate of small white lamellæ, dully transparent, brilliant, marked with longitudinal streaks parallel to each other, closely adhering together, but easily separated by the hammer, giving sparks with steel more readily than the lava; and, in the full light of day, exhibiting that changing colour which usually accompanies this stone. The largest are ten lines

long and six broad, and the smallest exceed one line. The shoerls are also found in the lava, in the same manner, and are so fixed in it, that they occupy nearly the half of it. It is impossible to extricate them entire. They are distributed within it without any order, and frequently cross and intersect each other at right angles.

In some situations of this lava, which are more than other exposed to the inclemency of the air and seasons, the feltspars are visible on the superficies, by a mixture of emerald and paonazzo, probably occasioned by the action of the atmosphere, as from the same cause some volcanic vitrifactions acquire externally their peculiar colour.

This lava has not equal solidity throughout, being in some places porous, or rather cavernous; and, in some of its varieties, it was remarkable, that it abounded with specular iron. This was found in very thin leaves, for the most part closely connected together. These are extremely friable; and the finger being passed over them, they adhere to it like particles of mica. But their small size, which, in the largest, is scarcely a line, renders it necessary to make use of a lens to examine them properly; by the aid of which we shall find that they are of very different shapes, have the lustre of burnished steel, and that many of them appear to be an aggregate of small thin scales, closely united.

This iron acts on the magnetic needle, at the distance of two lines. Like many other irons exposed to the air, it has acquired polarity; attracting the needle on one side, and repelling it on the other.

When we extract these thin scales of iron from the lava, and examine them with the lens, there frequently appear, intermingled with them, various fragments of microscopic transparent prisms, which I at first thought to be shoerls, or feltspars; but which afterwards I rather conceived to be zeolites, as they exhibited the appearance of radii diverging from a centre: but their extreme minuteness rendered it impossible accurately to ascertain their species.

Proceeding along the road to Solfatara, we find on the left hand a natural ridge of rock, formed of a very light lava, the base of which is horn-stone, of the colour of blue baked brick, of a coarse earthy grain, which attaches slightly to the tongue, and gives an ar-

gillaceous scent, on wetting it, or even merely moistening it with the breath *.

It is very probable that this lava has been decomposed, and that the decomposition has penetrated to the feltspars with which it abounds, as they are become very friable, though they in general still retain their natural brilliancy.

Having made these cursory observations, I proceeded to Solfatara: nor did I satisfy myself with one visit only, but repeated it several days; being extremely desirous carefully to examine, and gain every information relative to a place so celebrated.

From reading the notes of M. Dietrich to Ferber's Travels in Italy, I had been induced to imagine that Solfatara was a mountain isolated on every side †; but the truth is, it is connected with the other neighbouring mountains, with which it forms an uninterrupted chain of considerable extent.

It would be but of little utility for me to describe at length the form, extent, and circuit of this Phlegrean field; the various qualities of the hot vapours which exhale from it; or the hollow noise which is heard on striking the ground in various parts of it; not that these circumstances were not carefully examined by me, or that I think them unworthy of my narrative, but because it appears to me unnecessary to enlarge on them, as they have been already repeatedly described by a great number of travellers. It will, in my opinion, be more agreeable to the naturalist to proceed to a minute examination of the principal productions of this yet unextinguished volcano, as they have hitherto been, for the most part, either unobserved or passed over in silence.

In the obscurity and uncertainty in which we find ourselves, relative to the causes productive of subterraneous conflagrations, the spontaneous inflammation of sulphures of iron (or pyrites) has been considered as one of the most probable. The well-known experiment of Lemery, by which a similar conflagration is produced by

* 'In many lavas, the scent of clay is perceived, on moistening them with the breath, or by other means: whenever, therefore, I may hereafter mention the argillaceous scent of lava, I always understand it to have been subjected to this humectation, thoguh I omit to mention it, to avoid prolixity.'

† La Solfatare représente encore aujourd'hui une montagne assez élevée et isolée de tous côtés.—*Lettres sur la Mineralogie, &c. de l'Italie, &c.*

mixing filings of iron with powdered sulphur properly moistened has given great support to this opinion. But sulphures of iron, in volcanic countries, are less frequent than has been supposed. This has been clearly proved by the accurate observations of mineralogists who have written on them. And though Sir William Hamilton expressly affirms that both Etna and Vesuvius abound with them*, it is now well known that he mistook the shoerls for sulphures of iron (or pyrites), from want of mineralogical knowledge. In fact, Signior Dolomieu, in his Catalogo Ragionato de' Prodotti dell' Etna, mentions only one single piece of lava as containing sulpure of iron: and the Chevalier Gieoni, in his Litologia Vesuviana, has never noticed any such production. In Vulcano and Stromboli, two islands which are in a state of actual conflagration, I could trace no vestiges of such sulphures. As the same kind of substance, therefore, is found diffused in several parts of Solfatara, I think it well deserves that we should carefully consider it, and the bodies with which it is found united.

I. The stones which I here undertake to describe are principally found in the interior sides of Solfatara. The first I shall mention exhibits, both externally and internally, a number of shining particles, which, when examined by the lens, appear to be small aggregates of sulphure of iron, some crystallized in cubes, others in globes, and others in irregular figures. When the flame of the blow-pipe is applied to them, they begin to lose their yellow colour, which quickly, in consequence of their destruction, entirely disappears; when an odour slightly sulphureous is emitted.

This substance is a lava, the base of which is horn-stone; in part decomposed, light, friable, granulous, and of a cinereous colour.

II. The small sulphures of iron in this second lava are less numerous, but in their qualities very analogous to that already described, except that they are less decomposed and less friable.

III. The appearances exhibited by this lava are two. The external part is extremely white, and so decomposed that the slightest blow reduces it to powder; we likewise find in it some of the external characters of ordinary clay. It tenaciously adheres to the inside of the lip, is soft to the touch, and becomes still more so

* Both these mountains abound with pyrites.—*Campi Phlegræi.*

when slightly moistened. It absorbs water greedily, and with a kind of hissing noise; but is not reducible to a lubricious paste as clay is. But the internal part of this lava, besides being of a grey colour, is three-fourths heavier, and in its compactness, and its grain, approaches to that species of calcareous earth, called *calcareus æquabilis*, though, in fact, it only resembles it in appearance, not being reduced to calx by fire, nor dissolved by acids. In this lava, the sulphure of iron is not found in cubes or globes, but in thin lamellæ; and is dispersed throughout its whole substance, especially in certain parts, where the colour of the stone inclines to black, and has a greater consistency. No sign of this mineral appears in the white decompounded lava, probably because it was destroyed gradually, in proportion as the decomposition took place.

IV. This lava is much heavier than the three preceding; which, no doubt, arises from the greater abundance of sulphure of iron that it contains. The shining particles of this mineral are principally to be seen in its vacuities (of which, however, it has not many). They are polyhedrous, but the number of their faces is not constant. When exposed to the fire, it loses its brassy colour, burns with a thin blue flame, and emits a strong smell of sulphur. The lava which contains it, and which is of a livid grey colour, is in some situations so soft that it may be scratched with the nail, but in others much harder, and some of it will give sparks with steel. In this lava, the base of which appeared to me to be horn-stone, we find crystallized feltspars, but decomposed, though less so than the lava in which they are inclosed.

V. Around the extensive plain of Solfatara, we observe, in several places, a circular ridge of steep rocks, which once formed the upper sides of this enormous crater. The rain water, descending this declivity, over the decomposed lava, carries down with it the more minute parts to the lower grounds, where various concretions are produced, especially those stalactites which are commonly called *oolites*, or *pisolites* *. But of these stalactites we shall speak hereafter. Here we shall only notice, that this water, in its descent, carries down with it small pieces of decomposed lava, and that, in

* Varieties of the *Tophus oolithus* of the Syst. Nat. or the *Compact Limestone* of Kirwan.

some places, many of these pieces are found united, and bound together by a crust of sulphure of iron. It is black where it is exposed to the immediate action of the air, but, in the fractures of a shining appearance, though the colour inclines more to a lead-colour than to yellow. Its s ructure is scaly. The sulphures of iron which have before been mentioned give fire with steel; but this does not, from want of sufficient hardness. It abounds with sulphur; since, being exposed to the flame of the blow-pipe, it visibly melts, and, the activity of the fire being increased, a blue flame arises, which continues till the crust is consumed, nothing remaining but a very small quantity of a white pulverous earth, which is no other than a portion of decomposed lava, that had been united with this sulphur.

With this sulphur, the presence of which is extremely manifest from its strong smell, is also united arsenic; as sufficiently appears from the white fumes which arise from the combustion of the sulphure of iron, and which emit a very sensible odour of garlic.

These are the volcanic matters which, at Solfatara, abound more or less with sulphures of iron. But whence is their origin? It is well known they are formed by the combination of sulphur with iron. With the former this volcano abounds, whence it obtained the name of Solfatara; and, as the latter is almost always found mixed with volcanic productions, which commonly derive from it their varying colours, we have thus the two proximate principles of sulphure of iron. But is their combination effected by the dry, or, as is more probable, by the humid way? I find it difficult to conceive how it can take place by the first method, on account of the speedy dissipation of the sulphur sublimed by fire, which must prevent its uniting with the iron to form these sulphures. It appears to me more probable that they have been formed by the action of water, which having penetrated the lava, the sulphur, dissolving in the fluid, has combined with the iron. But as such solutions of sulphur in water seldom take place, as Bergman has observed, we rarely find sulphures of iron, in volcanized countries, notwithstanding the existence of these two minerals.

But let us continue the description of the productions of this celebrated place, the greater part of which are decomposed lavas; though this decomposition, notwithstanding it has been noticed by several writers, has not, to my knowledge, been examined by any one with requisite care and attention.

VI. This lava is coloured on the upper part with a covering of yellow oxyde of iron, under which is a white decomposed stratum, to which corresponds another lower one of a cinereous colour, where the lava is much less changed. These two strata form a very strong contrast. The white may be cut with a knife, in some places more easily and in some less; adheres to the tongue, does not give sparks with steel, feels soft to the wet finger passed over it, has considerable lightness, and being struck with a hammer, gives a dull sound, like earth moderately hardened. On the contrary the cinereous stratum sounds, when struck with a hammer, like a hard stone, of which it also has the weight; is rough to the touch, scarcely at all adheres to the tongue, gives fire with steel, and cannot be cut with the knife. The white stratum in some places, is an inch thick, and in others more, but there are likewise places where it is only a few lines in thickness. The white stratum, in general, changes insensibly into the cinereous, but in some places the separation is sudden and abrupt.

The feltspars in this lava (for of these it is full) are prisms; the largest of which are ten lines in length, and the smallest the sixth of a line. In the cinereous stratum, notwithstanding a beginning decomposition may be perceived, the feltspars are unimpaired. On the contrary, in the more decomposed stratum, I mean the white, their decomposition is very apparent; they have all lost their transparency, though many of them still retain their splendour. Others have acquired a resemblance to a sulphate of lime that has remained some time in the fire; to which they might likewise be compared in softness, had they a little less consistence. Some of them are infixed in that part of the lava, the colour of which is between the cinereous and white, and here we find them less changed than in the stratum which is entirely white. Others have one part of them in the white, and the other in the cinereous stratum; in which case we find the part fixed in the latter stratum to have suffered nothing, but that in the former considerably. In short, from the inspection of this lava, it is manifest, that, in proportion as the nature of it is changed, the feltspars it contains undergo a change, except when the principle producing the alteration is unable to affect them. Besides these feltspars, we find incorporated with the lava a number of very small and almost invisible black shoerls, which are not distin-

guishable where the lava is white; less, perhaps, because they do not exist, than because they have lost their colour, in consequence of the decomposition.

This lava, which is of a margaceous base, does not liquify in the furnace, when its decomposition is considerable; but other parts of it, which have been less decomposed, are reduced to a kind of frit.

VII. Solfatara, perhaps, does not afford a lava more compact, hard, heavy, or of finer grain than this. Its composition is siliceous, its colour grey, it gives sparks strongly with steel, and, at the distance of two lines, attracts the magnetic needle. Its base is of the petrosilex, and it contains within it different feltspars and shoerls; but some of the latter have been melted by the fire, as appears from the bubbles or speckles occasioned by the liquifaction. This lava is covered with a very white crust, nearly an inch thick, produced by the decomposition it has undergone. The effects of the furnace on this lava, are nearly the same with those on the lava No. VI.

VIII. This lava is entirely decomposed. On the surface, and for some depth, it is white, and almost pulverous; but in the internal part the white colour changes into a reddish blue, and acquires a degree of hardness; though not too great to be cut with a knife. The feltspars, in which it abounds, have suffered different degrees of decomposition. Some of them, besides being calcined, attach strongly to the tongue. Others, when viewed with a common lens, appear full of filaments; but when examined with a deeper magnifier, these filaments appear to be no other than extremely thin, striated, and very friable laminæ. This production is infusible in the furnace.

IX. The feltspars, in this lava, occupy more than one-third of its mass. They are in shape flat prisms, and, except having somewhat less hardness, retain all the qualities which characterize the species of stone to which they belong. There are also a number of shoerls, which, from their extreme minuteness, appear like points, but are easily distinguishable, by their black colour, from the lava, which is whitish, and has greater consistence than that of No. VIII. It is likewise heavier; to which the quantity of feltspars but little changed, which it contains, undoubtedly contributes.

X. The shoerls which make so great a part of the other kinds of lava, are found so strongly adherent to them, that we usually can only separate them in fragments. The present lava, in this respect,

offers an exception which may be considered as recommendatory of it. It has acquired so great a degree of softness by its decomposition, that the numerous shoerls it contains may be detached from it entire. They are hexagonal prisms, truncated perpendicular to their axes, the faces of which are slightly striated lengthwise, and their colour is a yellowish black.

In this lava, the base of which appeared to me of horn-stone, another more remarkable peculiarity presents itself. On breaking it, the fractures discover a number of small caverns jewelled, if I may employ the term, with a multitude of extremely minute shoerls of different colours, some green, some yellow, others of a dark chesnut, but all similar, being hexagonal prisms, with rhomboidal faces, and each terminating in a dihedrous pyramid. Their angles are regular, their faces shining, and in part transparent. They sometimes form geodes in the body of the lava. To examine them a lens is necessary, and a good magnifier clearly to perceive other shoerls still more minute. These are infixed in the small cavities before mentioned, and though they are extended to a considerable length in front of the others before described, are so minute and numerous that a single cavity will contain a hundred of them. Every one of both these kind of shoerls has one extremity fixed in the lava, and the other in the air, and all together appear like a wood in miniature. I was at first in doubt whether I should consider them as shoerls or volcanic glass, as more than one instance has been known of such glass reduced to a capillary minuteness within lava. But the latter appeared to me improbable, because after all the observations that have hitherto been made, we are not yet certain that any volcanic glass has been found crystallized; for, with respect to the pretended crystallization of some glasses in Iceland, we have not facts which demonstrate it incontrovertibly. On the other hand, the minute corpuscles I have described, if not all, at least those which from their larger size are more descernible by the eye, have a prismatic figure, and analogy must induce us to conclude the same of the rest.

I incline to believe these infinitesimal crystallizations produced, after the cooling of the lava within the cavity in which they are found from extremely subtle shoerlaceous sediments by the filtration of water.

XI. The oolites, mentioned in No. V. lie in certain small channels of Solfatara, through which the water runs when it rains. They are either round, or somewhat flattened: rather more than half an inch in diameter, white as snow, extremely light, easily crumbled, and convertible into an almost impalpable powder. They adhere strongly to the tongue, and are composed of a number of thin scales. The formation, therefore, of this volcanic stalactites does not differ from that of the other species.

It would be superfluous to speak here of the sulphate of lime adhering to some kinds of lava, or of the sulphate of iron and the oxyde of red sulphurate arsenic, as these productions of Solfatara have already been sufficiently examined and described by others, and I have no particular observations concerning them which merit to be mentioned.

XII. It is not uncommon to find at Solfatara pumices of various species; and it is more probable that they have been thrown out of this volcano than from any of the others. We do not find them in great masses, as in other places, but in detached pieces and fragments. I shall only remark one particular relative to them, as it appears to me that in every other respect they perfectly resemble those already known. We now know that pumice is only a glass which wants but little of being perfect; and seems to require only a degree more of heat to become such. The transition from glass less perfect to perfect, may be perceived in some of these pumices in a very evident manner. In some places their texture is fibrous, and the fibres are vitreous; but without that smoothness, that lustre, and that degree of transparency, which are inseparable from volcanic glasses. But, following them with the eye, we perceive them consolidate, here and there, into masses of various sizes, which resemble a shining and smooth varnish, but are in fact perfect glass, as will sufficiently appear, if they be detached from the pumice, and examined separately. These are sufficiently hard to give sparks with steel, a property observable in every volcanic glass.

Having now described the principal productions of the interior part of Solfatara, I shall proceed to make a few observations on some which are found in its exterior; in that part which is next to the Pisciarelli, so called from the warm bubbling water which issues with some noise from the bottom of a little hill contiguous to this

volcano, and which has been long celebrated for its medicinal virtues. I collected here specimens of five kinds of lava; but, as in their general qualities they are analogous to those already described, I shall only mention them in a cursory manner.

XIII. The first specimen is a simple or homogeneous lava, in which, notwithstanding the most careful examination, I could not discover either shoerls, feltspars, or any extraneous body. In other respects, like those before mentioned, it is decomposed, adheres to the tongue, is friable, but without crumbling under the finger; its whiteness extends through its whole mass, and wherever it is broken has the taste of sulphate of alumine, (or alum).

XIV. The second specimen, through nearly half of it, exhibits a similar decomposition, and is of a white colour; but the other half, which is of a lead colour, has suffered little, gives sparks strongly with steel, and moves the magnetic needle at two lines distance. This lava has for its base the petrosilex. Both that part of it which is slightly decomposed, and the other which is more so, contain rhomboidal feltspars, of which the largest are about an inch in length. Their alteration is scarcely visible where the lava is least changed; and where it is more, they exfoliate with some facility, but retain a considerable degree of their natural hardness and splendour.

XV. The third specimen is a lava of a dark grey colour, siliceous where fractured, very compact, and which gives sparks with steel. It is of a petrosiliceous base, and contains abundance of feltspars and shoerls. But to shew these, it is necessary to divest it of a thick, whitish, and half-pulverous crust, produced by its decomposition. In this crust the shoerls and feltspars retain some consistence, but have lost, in a great degree, their lustre.

XVI. The fourth specimen contains within it a nucleus of a deep red colour, of the hardness and appearance of the carbonates of lime (calcareous earths), of a fine grain, but which is not dissolved or affected by acids, nor yields sparks with steel. It attracts the magnetic needle at the distance of one line. It contains a number of fissures, through which has penetrated, together with water, a quartzous matter, which has consolidated into a semi-transparent, and somewhat rough, covering. In this lava, which is but little decomposed, are found, dispersed, a number of small masses of sulphur of iron.

XVII. Small shoerls, and large crystallized feltspars, occupy the substance of this last lava, which is somewhat porous, but sufficiently hard to give sparks with steel. It is covered with a whitish-yellow crust, which flakes off with a knife, and a reddish tincture has penetrated to its internal part, which is of a blackish ground.

In these lavas of Pisciarelli, the decomposition has, likewise, been much more considerable, than in the feltspars and shoerls which they contain within them.

I do not pretend to be certain that I have enumerated all the species of lava to be found at Solfatara: it is possible there may be others unobserved by me. I am persuaded, however, that I have described the principal; and such as enable me to deduce from their qualities the following conclusions.

1. Almost all the species of lava hitherto described, are more or less decomposed, and this decomposition is usually accompanied with a proportionable degree of whiteness. This observation has been made by several authors; and first by Sir William Hamilton, and M. Ferber, who have endeavoured to account for the fact by a very plausible reason, which is, that the sulphureous-acid vapours, which issue from Solfatara, and must have been produced in an infinitely greater quantity, when the conflagration was at its height, penetrating the lava by degrees, have insensibly softened it, and given it a white colour. And, in fact, similar changes are observed to take place in a piece of black lava, exposed for a sufficient time to the fumes of burning sulphur. But it does not hence follow that this lava will be changed into an argillaceous substance, as the above-mentioned Swedish philosopher would have us believe; since, from a chemical analysis, it appears that an earth of that kind, combined with other principles, pre-existed in it, and has only been rendered manifest by the diminution of aggregation produced by the before-mentioned vapours.

It is likewise not strictly true that the walls, or inclosing sides, of Solfatara are every where white and decomposed, as we might infer from the description of M. Ferber. Those who look toward the south, indeed, are so, but not those which are situated in another direction, and especially those which front the north, which are of a blackish colour, and little, or not at all, decomposed. The Abbé Breislak, Director of Solfatara, who accompanied me when I

made my observations, suggested a very probable reason for this diversity of appearance in the different sides, observing that the sulphureous acid is less powerful to effect the decomposition of lava, and requires longer time, when the lava has considerable humidity; which humidity must be much less on the southern side, where the heat of the sun is greatest. In fact, he exposed a piece of solid lava, to a very humid sulphureous exhalation, at Solfatara, during two months, without producing in it the least decomposition.

2. The observations I have made, convince me that the alterations here described always take place in the upper part of the lava; and that, in proportion as we penetrate downwards into it, they become gradually less, and, at a certain depth, entirely cease. This, at first view, does not appear to accord with the effect of sulphureous vapours, which, rising from the bottom of Solfatara, and passing through the lava, might be expected to cause a greater change in the lower parts than the higher, from their having there greater heat, and consequently being more active. But we must consider that this may indeed be the nature of their action, where the lava is spongy, or at least very porous, but not where it is compact, and almost impenetrable to such vapours; as is that of Solfatara. And, in fact, we find that the sulphureous fumes which arise there, do not issue from the body of the lava, but always from fissures or apertures in it, or the subjacent tufa. These impediments, therefore, prevent them from acting except on the surface, when, issuing forth, they are driven over it by the wind, and, penetrating the lava, in a long course of time, produce the changes in question. We meet with few decomposed lavas, within which we do not find fragments of sulphur adherent, condensed there by the acids above-mentioned, and which are of the same kind with that produced in such abundance in Solfatara.

But what productive cause shall we assign for those sulphureous vapours, the slow destroyers of the lava, which continually issue from a number of fissures in Solfatara, in the form of hot white fumes? I can conceive no principle to which they can with greater probability be ascribed than those sulphures of iron, (pyrites), which abound at the bottom of the volcano, and decomposing, in consequence of a mixture with the subterraneous waters, slowly inflame,

and produce those hot sulphureous vapours, which evidently prove that the subterraneous conflagration is not entirely extinguished. The noisy effervescence, likewise which, in more than one place is heard under the plain of Solfatara, seems to give a certain indication of the decomposition of these sulphures

The streams of vapour, which arise from Solfatara, according to Father Della Torre *, in the night, appear like flame. No person can be more competent to ascertain the truth of this fact than the Abbé Breislak, who resides near the place, and who, when I questioned him on the subject, assured me that he had never observed any such appearance. It is, however, not impossible, but that, at the time he observed them, they might have undergone some change.

The vapours which arise from the ground of the Pisciarelli are very few, and almost insensible, though formerly they must have been numerous and strong, as may be inferred from the great decomposition and whiteness of the lavas found there. I have already mentioned the noise with which the springs that bear this name burst from the earth. They resemble a boiling cauldron. The reasons assigned for this phenomenon, by different authors, are various, but, hitherto, all conjectural. On applying the ear to the place where the spring issues, we may hear that the bubbling noise does not proceed from any great depth, but from a small distance from the surface of the earth. Were the ground, here, to be dug into, we might, perhaps, be able to discover this secret, the knowledge of which might prove advantageous to volcanic researches.

3d. We have seen that almost all the lavas of Solfatara contain within them shoerls and feltspars. But it has been proved that the changes occasioned in both the latter, by the action of sulphureous acids, are considerably less than those which take place in the lavas in their matrices; which difference must arise from the nature of these two stones, which is less liable to extrinsic injuries. We find them, in fact, firmly resist the power of the humid elements. To the south of Vesuvius, and at a little distance from Salvatore, I have found several pieces of very ancient lava, porous, and half-consumed by time, which, however, preserved unaltered their black crystallized shoerls.

* Storia del Vesuvio.

It has been observed that the houses of Pompeii, long since overwhelmed by Vesuvius, and now in part dug into and cleared, are found to have been built of lava. I have ascertained this fact on the spot. They are of a reddish colour, very dry to the touch, and some of them will crumble under the finger, evident proofs of the change they have undergone; but no such alteration has taken place in the shoerls they contain; they still retain the hardness and glassy splendour which is appropriate to that stone.

We likewise know that the feltspars are indestructible by the air, as appears in the porphyries of which they are a part.

4th. I have already remarked that the lavas of Solfatara usually have for their basis the petrosilex and the horn-stone. I shall add, that I have also met with the granite in them, though not in a large mass, but in small detached pieces, which induced me to doubt whether they properly belong to this volcano; and as they likewise appeared to me untouched by the fire, I rather inclined to believe them adventitious. This granite consists of two substances, quartz and shoerl.

But another production must not be forgotten, which forms large heaps on one side of the internal crater of this volcano. This is an ash-coloured tufa, of a middling consistence, in strata of various thickness, with the superficies of each stratum covered with a black crust, in which may be discovered manifest vestiges of plants. The Abbé Breislak, who first observed this tufa, after having shewn it me on the spot, gave me some of these impressions of plants to examine, conjecturing them to be some species of the *alga marina*, or sea-weed. While I was at Naples, I had not sufficient time to make an accurate examination of them; but this I afterwards made at Pavia, from several specimens of the same tufa. Some parts exhibited only the impressions of plants, but in others I found leaves. They are striated, with striæ running lengthwise, and, when touched with the point of a needle, easily break, and appear converted into a carbonaceous substance. At first I doubted whether they were plants of the alga; but, on examining them again carefully with a lens, and comparing the leaves found in the tufa with those of the natural alga, I was fully convinced they were.

This observation appeared, both to me and the Abbé Breislak, to be of considerable importance; since we may conclude from it, that

the part of Solfatara which is formed by this tufa, has once made a part of the bottom of the sea, and been thrown up by the action of submarine fires. Nor is it improbable that the rest of it has had the same origin, and that all the substances of this volcano have issued from the waters of the sea. Such we know to have been the origin of many other mountains, either now actually burning, or which have ceased to burn.

It is well known that, for a long time, alum and sal-ammoniac have been extracted from this half-extinguished volcano. The method employed for each was as follows. In the process for the alum, certain square places were cleared out in the plain of Solfatara, in which it effloresced, and the efflorescences were swept together, and, from them, by methods well known, the salt was collected purified. The sal-ammoniac was obtained by placing a number of pieces of tile round the apertures from which that salt issued, in the form of a subtle vapour, upon which the vapour was condensed. A description of these two methods is to be found in almost all the authors who have written on Solfatara; some of whom, with reason, censure them as imperfect, and consequently not likely to produce the profit which might be obtained.

But we may now hope that both these manufactures may become objects of importance, under the direction of the Abbé Breislak, and the liberal patronage of Baron Don Giuseppe Brentano, who has taken this celebrated Phlegrean field at a constant rent. The Abbé, proceeding on the principle that the quantity of alum procured from Solfatara must be proportionate to the area of the space on which it effloresces, instead of the narrow squares formerly appropriated to this purpose, and called *gardens*, has greatly extended the spaces allotted; and that the preparation of this salt may not be prevented by the rain-water draining into the bottom from the steep sides of the volcano, he has surrounded them with small ditches, with deep wells at intervals, which receives the water, and where it is soon absorbed by the spongy earth. In the lower part of these sides he has likewise opened a number of cavities equally proper to furnish alum.

The same principle appears to have guided the Abbé in his attempts to increase the quantity produced of sal-ammoniac, by making use of long and capacious tubes of earth, open at both extremities, and baked in the furnace. These receive, at their lower ends, the va-

pours abounding with this salt, which attaches itself to their inner sides, and forms there a crust, that in time increases to a considerable thickness. I have seen with pleasure at Naples the effects of these two methods; and it is expected they will be still more productive, when some alterations suggested by persons well acquainted with this business have been made.

Formerly sulphur was extracted from the crater of this volcano; but the small quantity of it, and the low price of the commodity, have caused this labour to be abandoned.

[*Spalanzani.*]

END OF VOL. I.

R. Weeks, Printer, 89, Chancery-lane.